CANADIAN AQUACULTURE
R&D REVIEW 2013

INSIDE:

Intensive production of Tilapia and Coho Salmon in a Recirculating Aquaculture System

Development of novel RNA-based treatments against ISAV

Detecting SNP association with resistance to sea lice in Atlantic Salmon

Developing a carrying capacity framework for Baynes Sound, BC

Support for the development of a draft sediment monitoring program for freshwater cage aquaculture

Aquaculture Association of Canada Special Publication 23

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Front Cover: Juvenile Atlantic Salmon, courtesy of Ted Sweeten (DFO)
Back cover: Oyster raft in Bayne's Sound, BC, courtesy of DFO (Linda A. Fear)

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INTRODUCTION

Welcome to the fifth edition of the biannual Canadian Aquaculture R&D Review. The review is an ongoing compendium of the aquaculture research and development projects that have been underway over the past two years from all across Canada. The review contains over 220 project descriptions detailing an impressive range of topics, disciplines, species and geography. Projects include marine and freshwater species, and range in topic from fish health, production, husbandry technology, nutrition, integrated multi-trophic aquaculture, environmental interactions, and more.

This is the second issue of the review that has been produced by Fisheries and Oceans Canada (DFO) in partnership with the Aquaculture Association of Canada (AAC). This partnership is ideal, highly relevant, and mutually beneficial to our roles in the area of knowledge mobilisation at both the AAC and DFO. This collaboration has allowed us to produce this 2013 edition as an AAC Special Publication.

Since the beginning of the 21st century, aquaculture has played an increasingly important role in human nutrition, with aquaculture products now heavily involved in the food distribution chain. Development of responsible aquaculture not only presents biological, technological, and environmental challenges, but also requires inter-sectoral approaches where the economy, the legal system and the broad area of social sciences are increasingly called upon to intervene. The AAC wants not only to showcase advances in aquaculture in Canada, but also provides information to its members for an expanded dialogue on present and future challenges for this industry. This publication falls within AAC's mandate of disseminating knowledge and it should be of interest to a wide audience. Likewise, Fisheries and Oceans Canada has a mandate to enable the sustainable development of Canada's aquatic resources, including aquaculture, and to provide access to information on its scientific activities underway within the department and elsewhere in Canada. Publication of ongoing research in the AAC Bulletin is one important tool towards achieving our shared mandates and to reach out to interested stakeholders and the public.

We would like to take the opportunity to recognize and thank several people who contributed significantly to the production of this Review. First, Dr. John Martell (DFO) undertook the overall coordination of this project and was singularly instrumental in seeing this project through to completion from beginning to end. Johannie Duhaime provided key support in reviewing and editing all submissions. Tara Donaghy, Patricia Hunter, and Emily Nelson were also actively involved in various aspects of this project including editorial review as well as design, print, and online coordination. We would also like to thank Gail Ryan, the AAC Executive Director, for overseeing AAC's part in its publication.

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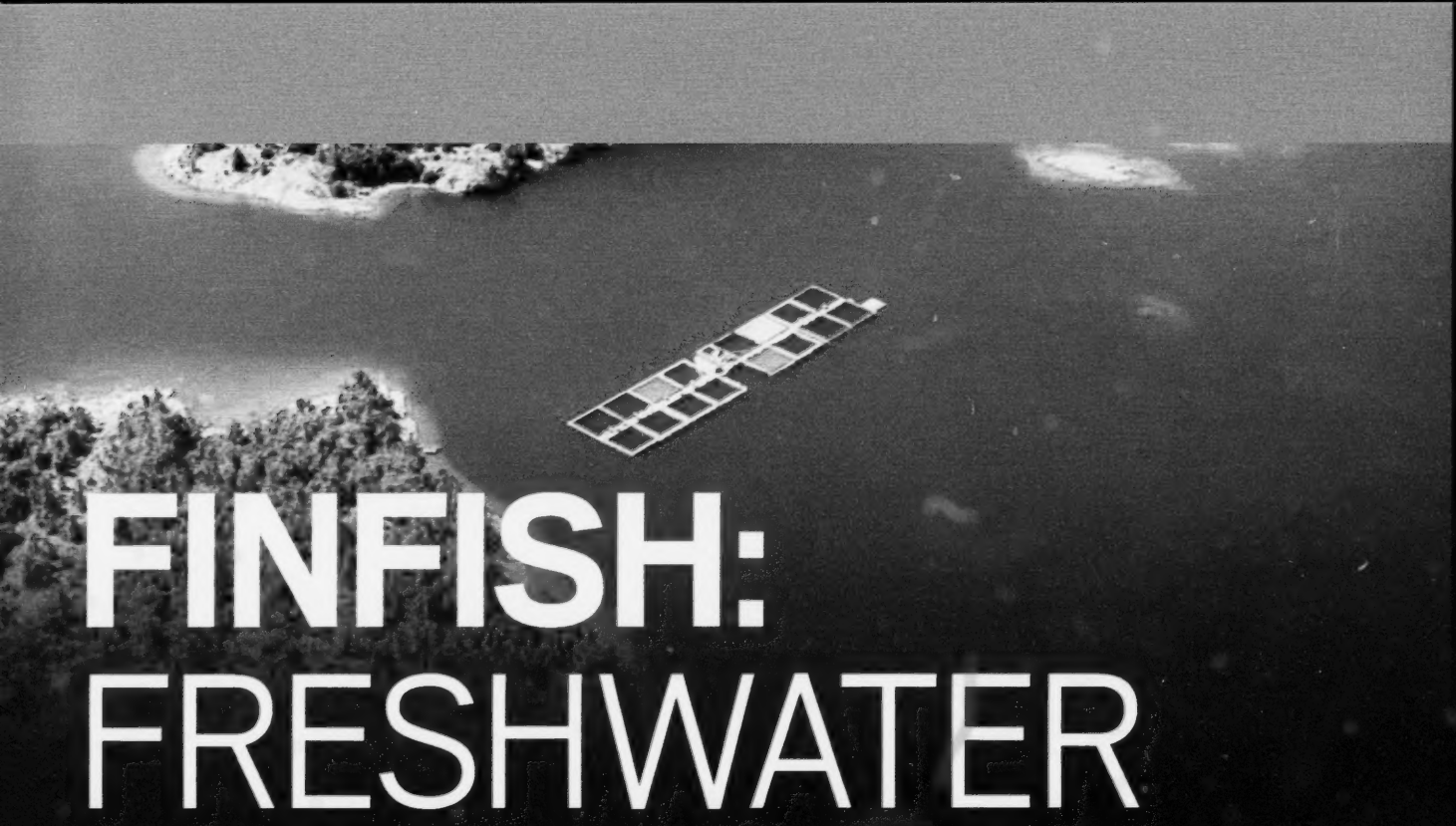


FINFISH: FRESHWATER

Striped Bass seedstock production and grow-out

Effect of a shrimp by-product to replace fishmeal in diets of Arctic Charr at early stage

Sex-linked markers for Arctic Charr

Sturgeon: Canada's diversified freshwater aquaculture industry Phase 2

Development of an automatic distribution system for live feed, microdiets and prophylactic treatments for sturgeon larvae and early juveniles

Pre-commercial assessment of the zootechnical performance and bioassay of Arctic Charr cultured in brackish water

Sub-clinical effects and metabolism of the feed-borne *Fusarium* mycotoxin deoxynivalenol (DON) in Rainbow Trout

Sperm quality of hatchery-reared Lake Trout throughout the spawning season

Development of techniques for accelerated growth, maturation and egg development for cultured Shortnose Sturgeon

Optimization of commercial feed adapted for the Manitoba – Canadian Model Aqua-Farm

Intensive production of Tilapia and Coho Salmon in a land-based, indoor, mixed-cell raceway, Recirculating Aquaculture System (RAS) – Phase 1 Tilapia

Effects of feed restriction on nutrient partitioning: priorities between body compartments in two size-classes of Rainbow Trout

Establishment of a pedigreed Rainbow Trout broodstock using recirculating aquaculture technology and genotyping

Ovarian fluid influences sperm performance in Lake Trout

Development of hatchery and advanced fingerling innovations to compliment North Shore Fish Farms Ltd. advanced indoor Yellow Perch recirculating aquaculture system and grow-out technologies

The effects of Bisphenol A (BPA) on reproduction, growth development and stress response in Rainbow Trout

Effect of composition of diet and the dynamic of digestion and absorption of amino acids on efficiency of utilization of dietary protein in Rainbow Trout

Characterize the response of vertebral bone tissue with a phosphorus deficiency in cultured Rainbow Trout through transcriptome analysis

Development of strains of Arctic Charr, Brook Trout and their hybrids capable of effectively synthesizing linseed oil into polyunsaturated fatty acids (omega-3)

Determination of geosmin and 2-methylisoborneol concentrations in Rainbow Trout by *in-vivo* sampling using solid phase microextraction

Corn gluten meal and muscle pigmentation in Rainbow Trout

Strategy for improving the beneficial properties of cultured fish for human health: inclusion of a new vegetable oil in the diet of trout

Optimization of omega-3 content and antioxidant capacity of flesh of strains of cultured charr

Evaluation of ration reductions on the growth, feed conversion, pigment retention and somatic indices of Rainbow Trout

Strategies to prevent off-flavours in fish raised in closed-circuit aquaculture system

Histological observations on vertebral bone remodelling upon the appearance, recovery and deterioration of a vertebral anomaly in cultured Rainbow Trout fed a diet low in phosphorus

Genetic and ecological impacts of Brook Trout stocking: issues affecting the ecological and economic sustainability of the aquaculture industry in Quebec

Study of the Brook Trout in terms of the functional and physiological genomic bases of performance characteristics, hybrid vigour and interest for aquaculture

Construction and evaluation of a new sludge and floating materials concentrator by use of sedimentation and mechanical recuperation suitable for fish farming

Design and validation of a new generation of rearing pond that permits rapid recovery of fish waste

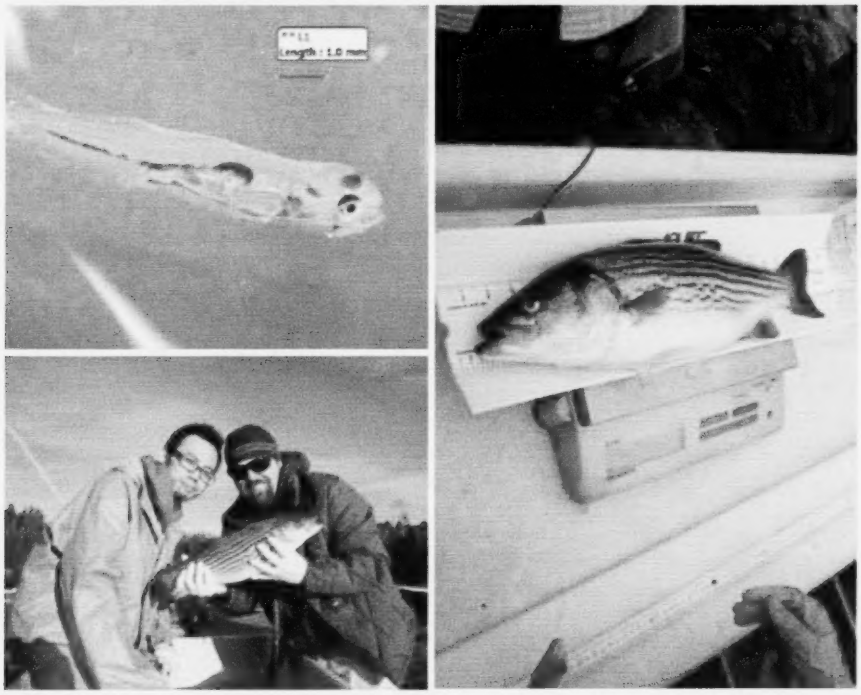
Nanaimo land-based Steelhead model aquafarm

The effect of dietary intake of phosphorus on P status and bone metabolism of Rainbow Trout

Research to improve the quality of eggs and early development of the Yellow Walleye for aquaculture in Quebec

Implementation of commercial mode zootechnical measures for maximizing rearing productivity of Arctic Charr

STRIPED BASS SEEDSTOCK PRODUCTION AND GROW-OUT



TOP LEFT: Nine day post hatch larva showing inflated swimbladder and orange Artemia in gut. *Photo: Paul MacIsaac (Dalhousie U.).* BOTTOM LEFT: Juvenile farm-reared striped bass (Scott Jeffrey and student Yuan Fan). *Photo: Jim Duston (Dalhousie U.).* RIGHT: Two kilogram Striped Bass on a balance. *Photo: Jim Duston (Dalhousie U.)*

The good market potential for farmed Striped Bass is evident, but has not been exploited in Atlantic Canada due to difficulties spawning and uncertainty on grow-out methods. We produced broodstock from eggs collected from the wild and since 2010 have achieved reasonably predictable and successful tank spawning, and high percent swim bladder inflation among larvae. Juveniles are fully euryhaline and have no early sexual maturity problems. Several thousand seedstock have been provided to a local farmer to assess grow-out potential in net-pens in man-made freshwater ponds. Food conversion and health of fish has been good to date. Ongoing work aims to further improve spawning success, define salinity requirements during the late-larvae/early juvenile stage, and determine optimum stocking densities for grow-out.

MAY 2007 – ONGOING

FUNDED BY: Canadian Centre for Fisheries Innovation (2009); NSDFA (2010)

PROJECT LEAD: Jim Duston (Dalhousie U.)

PROJECT TEAM: Paul MacIsaac, Scott Jeffrey (Dalhousie U.)

COLLABORATORS: North River Fish Farms Ltd. (Mike Cameron)

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SEX-LINKED MARKERS FOR ARCTIC CHARR

This project integrated hormonal sex manipulation into a major breeding program for Arctic Charr in Atlantic Canada to produce all-female population. The specific objectives were to: 1) masculinise experimental families coming from F4' generation of Arctic Charr from the Fraser strain; 2) identify microsatellite molecular markers useful for identifying genetic sex in the experimental families of Arctic Charr to identify genotypic females in the masculinised experimental families for future broodstock; 3) fertilize eggs from normal females using indirect feminization techniques; and 4) produce all-female population of Arctic Charr broodstock of known pedigree and good growth performance.

DEC. 2009 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Merlin Fish Farm Ltd.

PROJECT LEAD: Brian Glebe (DFO)

PROJECT TEAM: Tillmann Benfey (UNB); Moira Ferguson (U. Guelph)

COLLABORATORS: Paul Merlin (Merlin Fish Farm Ltd.)

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EFFECT OF A SHRIMP BY-PRODUCT TO REPLACE FISHMEAL IN DIETS OF ARCTIC CHARR AT EARLY STAGE

The objective was to evaluate the effect of a shrimp process residue meal (SPRM) on performance and health of Arctic Charr (*Salvelinus alpinus*) at early stage fed low fishmeal diets. The SPRM was obtained from shrimp by-product sludge in a seafood processing plant. The sludge was dried to produce the SPRM, which contained high concentrations of beneficial nutrients (71% proteins, 14% lipids, omega-3 (30% of lipids), >60 µg/g vitamin E). One practical (control) and three experimental diets were formulated with graded levels of shrimp by-product to replace 25, 50, and 100% of fishmeal. One commercial starter feed for salmonids was also used for comparison. Arctic Charr (0.90 g) were allocated to 30 100–L tanks. Growth and feed efficiency (FE) were higher for the fish fed the control and experimental diets than for those fed the commercial. At the end of the eight-week trial, fish fed 25% and 50% SPRM had significantly higher growth (TGC=0.127, final body weight =5.7 g) and FE (1.2) than fish fed 100% SRM or commercial feed ($P \geq 0.05$). Fish fed the control diet had higher performance overall (TGC=0.130, FE=1.3 and FI=4.0 g/fish). SPRM represents a valuable candidate ingredient in feeds for carnivorous fish.

APR. 2012 – JUNE 2012

FUNDED BY: Department of Agriculture, Aquaculture and Fisheries of New Brunswick **CO-FUNDED BY:** Regional Development Corporation of New Brunswick; New Brunswick Innovation Foundation

PROJECT LEAD: André Dumas (CZRI)

PROJECT TEAM: Claude Pelletier, Gilles David, Sylvie Levesque (CZRI)

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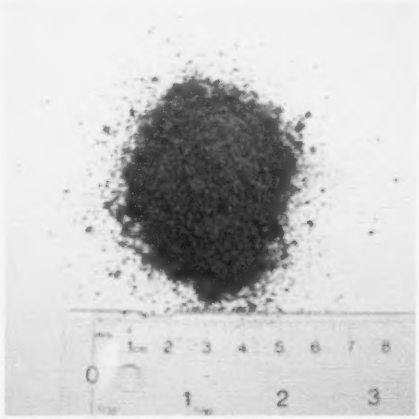

Shrimp process residue meal (SPRM). *Photo: André Dumas*

STURGEON: CANADA'S DIVERSIFIED FRESHWATER AQUACULTURE INDUSTRY PHASE 2

Sturgeon technician Andrew Obermeyer relocates a mature White Sturgeon weighing ~100 kg.
Photo: Target Marine Hatcheries Ltd.

Twelve years of Target Marine's investment in and developing White Sturgeon culture has successfully grown sturgeon from egg to over 100 kg in size and has resulted in essential expertise required to increase the diversification of the Canadian freshwater aquaculture industry. The large size and nature of the animals required an investment in developing and implementing improved innovative fish handling techniques.

The objective of this project was the implementation of a safe and efficient handling method for large sturgeon during sorting, staging, spawning, and harvesting. The project has successfully resulted in the development and implementation of a safe and efficient holding and handling method for moving large animals within the Target Marine facilities. The methods and equipment were implemented and evaluated during the sorting of maturing female fish destined for caviar production. The handling equipment will be fundamental for sorting different stages of production fish and handling broodstock into the future. It will also be used for harvesting the caviar fish. Under the highest environmental performance and traceability, Canada can become a new competitor in the global farmed caviar trade, while easing the pressure on endangered wild stocks.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Justin Henry (Target Marine Hatcheries Ltd.)

PROJECT TEAM: Justin Henry, Robert Haines (Target Marine Hatcheries Ltd.)

COLLABORATORS: Joel Van Eenennaam (U. California Davis); Faculty and staff members (VIU — Int. Centre for Sturgeon Studies)

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PRE-COMMERCIAL ASSESSMENT OF THE ZOOTECHNICAL PERFORMANCE AND BIOASSAY OF ARCTIC CHARR CULTURED IN BRACKISH WATER

The project objective was to assess the pre-commercial zootechnical performance and bioassay a batch of Arctic Charr (Fraser strain) grown in brackish water (average salinity of 12.5 ppt). The fish had an average initial weight of 60.7 g and were kept at an average temperature of 9°C for over seven months. The average final weight of the fish was 765.8 ± 215 g at 2028 degree-days. The feed conversion rate was 1.07 with an average feed ration of 1.33 percent, whereas the overall thermal growth coefficient was 0.26. Over the course of the project, the mortality rate was at the low level of 1.6 percent.

In a sample of 83 Arctic Charr with an average weight over 1 kg, no maturity was observed. The Arctic Charr condition index was 1.84, whereas the yield after evisceration was 88.8 percent.

These results allow us to conclude that the brackish water used in the project is well suited to the commercial farming of Arctic Charr.

SEPT. 2011 – APR. 2012

FUNDED BY: NB DAAF **CO-FUNDED BY:** IRAP; CZRI; Marc Cormier; the town of Shippagan.

PROJECT LEAD: Claude S. Pelletier (CZRI)

PROJECT TEAM: Caroline Roussel, André Dumas, Joël Cormier, Gilles David, Claude Landry (CZRI)

COLLABORATORS: Michel Desjardins (MAPAQ)

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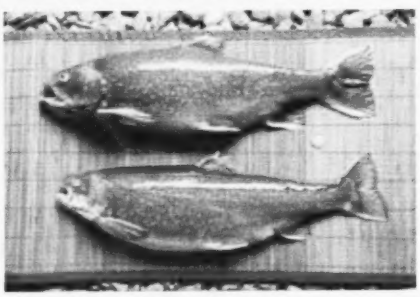
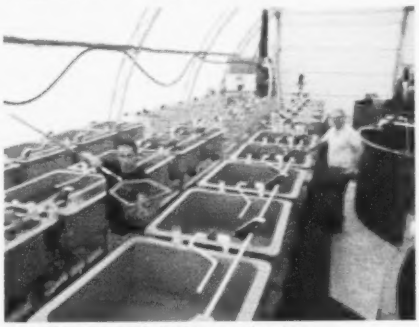


Arctic Charr grown in brackish water.
Photo: Joel Cormier (CZRI)

DEVELOPMENT OF AN AUTOMATIC DISTRIBUTION SYSTEM FOR LIVE FEED, MICRODIETS AND PROPHYLACTIC TREATMENTS FOR STURGEON LARVAE AND EARLY JUVENILES



View of the Carters Point Sturgeon hatchery.
Photo: Cornel Ceapa (Acadian Sturgeon and Caviar Inc.)

One of the major constraints in developing a viable sturgeon aquaculture industry in Canada is larval rearing and early juvenile production. Most sturgeons are fed a natural diet, usually *Artemia* (brine shrimp), for the first 3 to 4 weeks of their life following which they are gradually weaned on the artificial microdiet. Those technological operations are labour intensive; the diets are very expensive and overfeeding impacts tank hygiene and implicit survival.

In order to address and solve the problems related to live feeding, prophylactic (salt) treatments and weaning on artificial micro diets, Acadian Sturgeon and Caviar purchased and modified an automated microdiet dispenser (AMD) system from the Department of Fisheries, Western Australia, with the goal of optimizing the feeding and treatment processes, and increasing sturgeon juvenile production.

This technology will have important positive impacts that include: improved general productivity; improved tank hygiene and survival; improved growth and quality of the live sturgeon produced for sale and for our own stocks; reduced labour costs; and reduced effluent pollution by reducing overfeeding.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** National Research Council (NRC-IRAP); Skretting.

PROJECT LEAD: Cornel Ceapa (Acadian Sturgeon and Caviar Inc.)

PROJECT TEAM: Paymon Roustaian (Acadian Sturgeon and Caviar); Nick King (Skretting); Sagiv Kolkovski (Department of Fisheries, Government of Western Australia)

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SUB-CLINICAL EFFECTS AND METABOLISM OF THE FEED-BORNE *FUSARIUM* MYCOTOXIN DEOXYNIVALENOL (DON) IN RAINBOW TROUT

Contamination of feeds with mycotoxins is an issue of increasing importance in aquaculture due to the use of plant ingredients. In a previous study, we found that Rainbow Trout are extremely sensitive to low dietary levels of the *Fusarium* mycotoxin, deoxynivalenol (DON). Consequently, this study will seek to determine the basis of this sensitivity by examining the sub-clinical effects and metabolism of DON in Rainbow Trout. The effects of diets containing low, graded levels of DON from naturally contaminated and purified sources on pathological changes of various tissues/organs will be examined. Following the development of a robust enzyme assay, the contribution of UDP-glucuronosyltransferase (UDP-GT), a phase II conjugative enzyme, to species-specific sensitivity will be investigated in Rainbow Trout and common carp, a highly tolerant omnivorous species. Hepatocyte cell cultures and LC-MS/MS will be utilized to determine the pattern of metabolites in these species with particular focus on the glucuronide conjugate and de-epoxy DON (DOM-1), a widely studied metabolite of DON detoxification produced by ruminal and/or intestinal microbes. Elucidation of the sub-clinical effects and characterization of detoxification processes associated with DON exposure are critical for the development of nutritional mitigation strategies, preventative screening programs and suitable *in vivo* biomarkers of exposure.

SEPT. 2010 – SEPT. 2013

FUNDED BY: Biomin (B.R.A.I.N program)

PROJECT LEAD: Dominique P. Bureau

PROJECT TEAM: Jamie M. Hooft, Rudolf Krska, Michael Sulyok, E.J. Squires, John Lumsden, Dominique P. Bureau (U. Guelph)

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DEVELOPMENT OF TECHNIQUES FOR ACCELERATED GROWTH, MATURATION AND EGG DEVELOPMENT FOR CULTURED SHORTNOSE STURGEON

Breviro Caviar is the only commercial producer of Shortnose Sturgeon caviar and meat products in the world. The company operates three hatchery and grow-out facilities located in St. Andrews, Pennfield, and Charlo, NB. Several years of sturgeon production and directed research at the Pennfield and St. Andrews sites has indicated that growth, maturation, and egg development of Shortnose Sturgeon could be enhanced significantly by maintaining the fish continuously in elevated water temperature and high oxygen/ low nitrogen environments. Currently, the culture infrastructure at Breviro sites does not allow economical heating of the water to produce optimal temperature environments and relies only on conventional oxygen infusion equipment.

This project proposes to build a commercial-scale recirculation system in Charlo, NB, to study and subsequently commercialize this system. The objective of the AIMAP project is to compare the growth, maturation rate and egg development of Shortnose Sturgeon held in two recirculation systems. It is suggested that the high temperature/oxygen environments will allow much more rapid progression of these biological parameters which are essential to enhance the economics of Shortnose and other sturgeon culture in Canadian environments.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Charlo Salmonid Enhancement Centre

PROJECT LEAD: Jonathan Barry (Breviro Caviar Inc.)

PROJECT TEAM: Jonathan Barry, David Cassidy, A. Kinney, W.E. Hogans (Breviro Caviar Inc.); Onassis Sanchez Diaz (SilkStevens Engineering); Michel Belanger (Charlo Salmonid Enhancement Centre)

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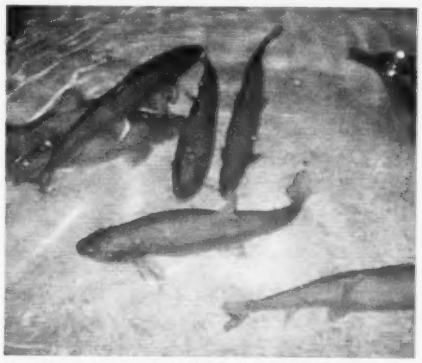
Breviro technician, Bill Wentworth holds a juvenile Shortnose Sturgeon. *Photo: Breviro Caviar Inc.*

SPERM QUALITY OF HATCHERY-REARED LAKE TROUT THROUGHOUT THE SPAWNING SEASON



Lake Trout broodstock. *Photo: Ian Butts (U. Windsor)*

The objective of this study was to investigate variation in sperm quality metrics (motility, velocity, linearity, longevity, and density) of hatchery-reared Lake Trout, *Salvelinus namaycush*, throughout the spawning season. Seasonal variation in sperm quality was investigated using both a regression and repeated-measures approach. Sperm was collected from the same 16 individuals over four sampling periods, separated by 3-week intervals, spanning the natural spawning season. Regression analyses showed that 7 to 27% of the variation in sperm traits could be explained by seasonal variation, indicating that seasonality can have a significant impact on the quality of sperm. Significant positive linear relationships were found for percent motility and linearity at 5 s post-activation. Significant negative quadratic relationships were found for velocity at 5 s post-activation, longevity and density, while a positive quadratic relationship was found for linearity at 10 s post-activation. Repeated measures ANOVAs showed a significant effect of season for percent motility and linearity at 5 and 10 s post-activation, velocity at 10 s post-activation and longevity. The present study is important for optimizing fertilization protocols for hatchery production and can also be used to understand reproductive biology and ecology of wild Lake Trout stocks.

JAN. 2010 – JUNE 2011

FUNDED BY: NSERC; Ministry of Research and Innovation postdoctoral fellowship grant

PROJECT LEAD: Trevor E. Pitcher (U. Windsor)

PROJECT TEAM: Katelynn Johnson, Ian A.E. Butts (U. Windsor), Chris C. Wilson (Ontario Ministry of Natural Resources, Trent U.)

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OPTIMIZATION OF COMMERCIAL FEED ADAPTED FOR THE MANITOBA – CANADIAN MODEL AQUA-FARM

The project seeks to adapt and validate a commercially available feed and optimize its formulation for use in the newly constructed MB – CMAF, a state of the art recirculating aquaculture system. Feed formula adaptation centres on the addition of an ingredient that acts to stabilize and improve feces consistency thus improving solids removal from the system and ensure optimal water quality. Although economic analysis of feeding Skretting's BioTrout diet has demonstrated significantly reduced feed costs, preliminary tests revealed significantly lower stability of feces from trout fed this diet. Given these results, there would be considerable risk feeding this diet to fish in recirculating systems; increased suspended solids would affect growth performance and fish health, but also negatively impact biofiltration efficiency. Addition of ingredients that stabilize feces to the BioTrout diet permits the utilization of a cost effective feed in recirculation systems.

WellWater Aqua Ltd. located in Warren, Manitoba, is the site of the ongoing MB – CMAF project, including a comprehensive environmental monitoring program onto which this project proposal is directed. Skretting Canada collaborates to provide support for diet development and Canadian Aquaculture Systems provides engineering and operational logistical support. Université Laval provides technical expertise and support for diet development and testing.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Rudy Reimer (Well Water Aqua Ltd.)

PROJECT TEAM: Daniel Stechey (Canadian Aquaculture Systems); Grant Vandenberg (IPSFAD); Cameron Robinson, Jeff Eastman (MAFRI)

COLLABORATORS: Manitoba Agriculture, Food and Rural Initiatives (MAFRI); Skretting Canada; Canadian Aquaculture Systems; U. Laval

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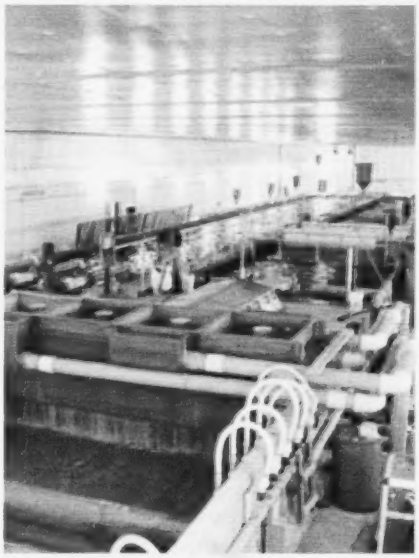

Production system at the Manitoba – Canadian Model Aqua-Farm. *Photo: Jeff Eastman (MAFRI)*

INTENSIVE PRODUCTION OF TILAPIA AND COHO SALMON IN A LAND-BASED, INDOOR, MIXED-CELL RACEWAY, RECIRCULATING AQUACULTURE SYSTEM (RAS) — PHASE 1 TILAPIA

Multi-cell raceway stocked with Tilapia. *Photo: Mandy Mielke (DFO)*

This project aims to convert and utilize a former mushroom composting building for the multi-species production of live market Tilapia initially and the additional production of Coho Salmon and other species (Arctic Charr) ultimately. The 70,000 square feet building has 12 large enclosed concrete "tunnels" that are ideally suited for use as the raceway portion of a mixed-cell raceway, recirculating aquaculture production system. Phase One will establish the initial conversion and commercial production of two tunnels for the production of live market Tilapia, for sale into Toronto Asian markets.

A unique aspect is the design version of the mixed-cell raceway for each tunnel that can be operated (with slight modifications) for either warm or cold water species in separate raceways, despite operating temperature requirements. This enables multiple species to be produced with a common design, and further enables switching of species mix should market conditions warrant. Further, as a result of new engineering developments that utilize low head oxygenation and new biofilter designs, recirculation is provided via a single recirculation circuit. This, along with more energy efficient oxygen generators, provides improved operating and cost efficiencies, particularly energy use, with some of the lowest production costs seen by the expert design team.

The improved recirculating aquaculture system mixed-cell technology design combines the advantages of hydraulic performance of round tank designs, with the advantages of better use of floor space and harvesting efficiencies of traditional raceway configurations. The proposed design provides efficient water use/reuse, zero environmental discharge off site (filter solids are managed via tank containment and "Geotube" dewatering), high security F1 indoor containment for biosecurity and development of new commercial species with minimal ecological risk, and low head pumping and bio-filtration technologies plus efficient on-site oxygen generation for minimal energy input.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Sand Plains Community Development Corp.

PROJECT LEAD: Kathryn Barbon (E&E McLaughlin Ltd.)

PROJECT TEAM: Kathryn Barbon, Ewart McLaughlin, Chris Hiney (E&E McLaughlin Ltd.); Gary Chapman (North American Tilapia (NATI) Inc.); John Holder (JLH Consulting)

COLLABORATORS: North American Tilapia (NATI) Inc.

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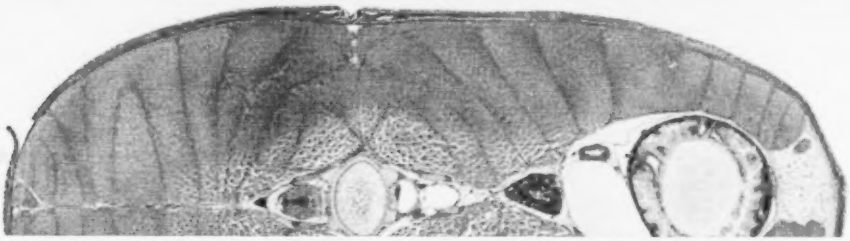

Effects of feed restriction on nutrient partitioning: Cross-section of a trout fingerling, posterior to the dorsal fin. Various organs are visible, including the white and red muscles (whose fibers were measured), vertebrae, kidney, and intestine. *Photo: Guillaume Salze*

EFFECTS OF FEED RESTRICTION ON NUTRIENT PARTITIONING: PRIORITIES BETWEEN BODY COMPARTMENTS IN TWO SIZE-CLASSES OF RAINBOW TROUT

Regardless of being in the wild or in culture conditions, food or feed restriction is quite common in fish. Causes include seasonal variations, dominance behaviour, poor water quality, nutrient deficiencies, diseases, etc. Fish have remarkably flexible growth, as they actively adapt and prioritize resources to meet their metabolic targets. However, these priorities remain poorly understood and may change according to life stage. The goal of this project was to quantify nutrient deposition in four groups of organs in two size-classes of trout. This information is important to understand better the coordination of nutrients deposition/mobilization, hence better predicting growth processes and nutrient utilization in a wider set of conditions. We show that restricted fish mobilize nutrients from mostly the white muscle, and preserve the red muscle as well as the viscera. Moreover, specific proteins are deposited in the muscle under different nutritional regimens, which may impact final product quality. Fingerlings of Rainbow Trout adapt to feed restriction by recruiting fewer muscle fibers while enlarging existing ones. Restricted juvenile strive to maintain body protein content, whereas fingerling attempt to maintain their protein and lipid contents. Taken together, these results highlight the different priorities between life stages, and sheds light into the orchestration of growth processes of different organs.

AUG. 2009 – DEC. 2011

FUNDED BY: NSERC

PROJECT LEAD: Guillaume P. Salze, Dominique P. Bureau (U. Guelph)

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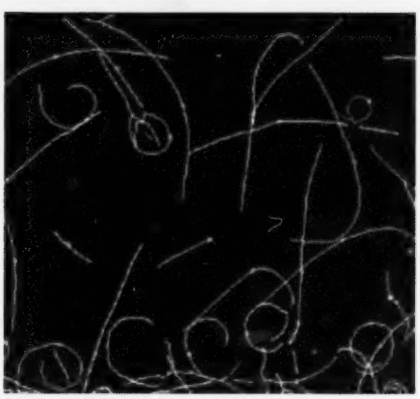
OVARIAN FLUID INFLUENCES SPERM PERFORMANCE IN LAKE TROUT



Sperm motility traits were analyzed using the HTM-CEROS sperm analysis system. *Photo: Ian Butts*

Studying interactions between gametes and their associated fluids can provide insights into the mechanisms that underlie the evolution of mating systems and can improve fertilization protocols for hatchery production. The objectives of this study were to determine whether: i) the presence and concentration of ovarian fluid affects sperm traits; and, ii) variation in sperm traits is due to male identity, female identity, and/or male × female interactions in Lake Trout. Sperm from four males were activated in both water and ovarian fluid from four females at two concentrations (10 and 15%). Results showed that the presence of ovarian fluid influenced sperm traits; however, no significant differences were detected between 10 and 15% ovarian fluid concentrations. Furthermore, sperm traits varied depending on male and female identity, such that some males perform better in the ovarian fluid of all females and that some females have ovarian fluid in which sperm traits are higher for all males.

JAN. 2011 – AUG. 2012

FUNDED BY: NSERC; U. Windsor; Ministry of Research and Innovation postdoctoral fellowship grant

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ESTABLISHMENT OF A PEDIGREED RAINBOW TROUT BROODSTOCK USING RECIRCULATING AQUACULTURE TECHNOLOGY AND GENOTYPING

While pedigreed broodstocks in aquaculture may already be well established in the United States and other countries, the targeted development of a selected pedigreed Rainbow Trout broodstock constitutes a significantly innovative initiative for Canadian freshwater aquaculturists. With this project, Lyndon Fish Hatcheries Inc. will continue to develop the first pedigreed Rainbow Trout broodstock in the country, which will ultimately work to reduce the vulnerability of Canadian growers who rely on eggs and fingerlings from selected broodstocks out of the United States. Lyndon's broodstock is characterized by a wide genetic base enabling year-round spawning and has been mass selected to improve production traits for approximately 20 generations with Canadian grow-out conditions in mind.

The main goal of this project is to identify individual broodstock across the entire Lyndon strain spawning cycle that has a superior growth genotype. This will be achieved using a combination of molecular genetic pedigree analysis and quantitative genetic evaluation methods. The marketable product for the industry will be superior growing progeny from selected broodstock. Additionally, funding has been obtained to look at coldwater disease susceptibility. A portion of the families created over the 2012/13 spawning season will also be evaluated for their resistance to coldwater disease.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Industrial Research Assistance Program (NRC – IRAP); Natural Sciences and Engineering Research Council (NSERC Strategic); Ministry of Agriculture, Food and Rural Affairs (OMAFRA)

PROJECT LEAD: Lynn Rieck (Lyndon Fish Hatcheries Inc.)

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Aerial view of Lyndon Fish Hatcheries. *Photo: National aerial view (Lyndon Fish Hatcheries Inc.)*

DEVELOPMENT OF HATCHERY AND ADVANCED FINGERLING INNOVATIONS TO COMPLIMENT NORTH SHORE FISH FARMS LTD. ADVANCED INDOOR YELLOW PERCH RECIRCULATING AQUACULTURE SYSTEM AND GROW-OUT TECHNOLOGIES

North Shore Fish Farms Ltd. (NSFF), located in southern Ontario, has and continues to advance land-based indoor recirculating culture methods for sustainable production of Yellow Perch. As a result of the AIMAP funding, NSFF has been able to proficiently and successfully design, construct, troubleshoot and implement two additional isolated recirculating aquaculture systems that will aid in promoting and supporting early life stage development of Yellow Perch.

Each independent system/process was designed to control conditions that promote growth at specific life stages (fry and advanced fingerling), in addition to providing opportunity of supplemental cohort group separation within each specific stage of growth cycle to optimize development rates and efficiencies.

These innovations generated an immediate increase in sustainable production output of Yellow Perch at different size classes (fingerling, advanced fingerling and market size). Additionally, successful execution of this multi-tiered land based rearing system will accomplish reduced operating overheads that can be used as an economically viable operating model for urban aquaculture across our country.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

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PROJECT TEAM: Frank Causarano, John Causarano, Christine Causarano, Alex Causarano, Nicholas Causarano, Mark Night, Dale Tiessen (North Shore Fish Farms Ltd.)

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Yellow Perch ready for market. Photo: Dale Tiessen (North Shore Fish Farms Ltd.)

THE EFFECTS OF BISPHENOL A (BPA) ON REPRODUCTION, GROWTH DEVELOPMENT AND STRESS RESPONSE IN RAINBOW TROUT

Bisphenol A (BPA) has been measured in the Grand River, and the muscle of fish inhabiting this water body. While the accumulation of this chemical in the fetus leads to multi-generational effects in mammals, we know very little about long-term effects of BPA exposure in fish. Here we are proposing to test the multi-generational effects associated with BPA accumulation in fish eggs. The rationale behind this paradigm is that contaminants such as BPA, which accumulate in tissues, are transferred to the eggs from the mother. This may have huge implications in developmental programming events. Here we are asking the question whether BPA accumulation in eggs of Rainbow Trout, mimicking maternal transfer, can lead to phenotypes compromised growth and stress responses in the F1 generation. A multi-tiered approach comparing genes in trout phenotype along with changes in genome and metabolic pathways (termed "OMICs" in this proposal) in the F1 generation will be undertaken. Such "OMICs" responses will be compared with other physiological measures, including changes in hormone levels and their action, in response to growth and stress, as indicators of altered fish performance. Collectively, the results will allow us to develop novel risk assessment tools that will increase our capacity for predicting population-level damage. The knowledge and understanding of generational effects induced by BPA accumulation in eggs, and the development of markers that will predict these effects, will be useful tools for Canadian government managers monitoring the aquatic environment, and for industry environmental toxicologists.

This study will provide insight into the mode of action of BPA. Moreover, candidate genes that are targets for BPA will be identified and will assist with the development of molecular markers during early life stages for predicting long-term effects, including reproductive success. The research conducted as part of this study could be used to assess the long-term impacts associated with maternal transfer of chemicals commonly found in Canadian fresh waters, such as those released from agriculture and urban runoff. The study will not only establish the phenotypic traits that are disrupted by chemical exposure during a critical period of development, but will also identify mechanisms that will result in long-term effects in fish and in their offspring, to better predict the impact that chemicals and numerous xenobiotics have on aquatic populations.

JAN. 2011 – FEB. 2013

FUNDED BY: NSERC Strategic Grant **CO-FUNDED BY:** Ontario Ministry of Agriculture, Food and Rural Affairs

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PROJECT TEAM: Alma Aquaculture Research Station (U. Guelph)

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EFFECT OF COMPOSITION OF DIET AND THE DYNAMIC OF DIGESTION AND ABSORPTION OF AMINO ACIDS ON EFFICIENCY OF UTILIZATION OF DIETARY PROTEIN IN RAINBOW TROUT

Fish feed formulation is increasingly relying on a variety of plant protein sources. These economical protein sources often have poor digestible essential amino acid (EAA) profiles. Closer attention need to be paid to adequately meeting the essential amino acid requirements of fish. It has been suggested that dynamic of digestion of protein and absorption of amino acids and metabolic interactions between amino acids may have a significant influence on the efficiency of amino acid retention by fish.

The focus of the project is on enhancing our understanding of the dynamics of digestion, absorption and utilization of amino acids as a function of dietary amino acid composition. The project involves a series of feeding trials and elaborate sampling protocols to look at amino acid digestion, absorption and retention. A model integrating information derived from the feeding trials and sampling protocols will be developed to describe the complex issue of the dynamic of digestion and absorption and efficiency of retention of amino acids in Rainbow Trout.

SEPT. 2010 – APR. 2014

FUNDED BY: NSERC Strategic

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CHARACTERIZE THE RESPONSE OF VERTEBRAL BONE TISSUE WITH A PHOSPHORUS DEFICIENCY IN CULTURED RAINBOW TROUT THROUGH TRANSCRIPTOME ANALYSIS

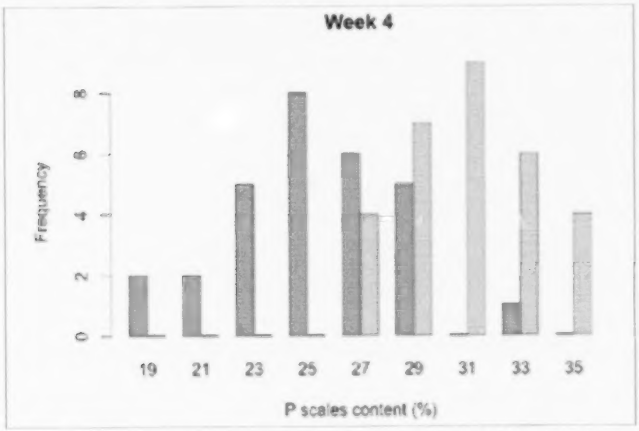

FIGURE 1: Distribution of individuals sampled (n = 120) at week 4 (end of the short-term experiment) according to their status and phosporus diet. Red: P-deficient diet; Green: P-sufficient diet. *Credit: Grant Vandenberg (U. Laval)*

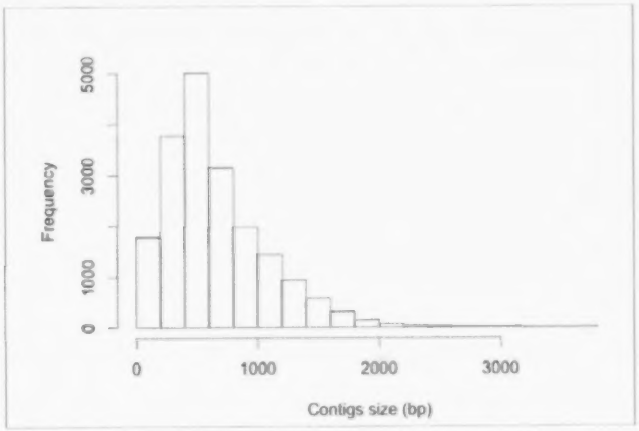

FIGURE 2: Distribution of the number of contigs obtained by de novo assembly (Newbler 2.6) along their length (bp). *Credit: Grant Vandenberg (U. Laval)*

In production, phosphorus (P) must be supplied through feed in sufficient but not in excessive quantity to ensure the animal's health and to prevent pollution. The overall objective of this study is to understand P metabolism at the molecular level in bone tissue so that it can be better managed. The administration of two diets, one P-sufficient and the other P-deficient, over a period of 27 weeks led to differences in the P status of the fish (Figure 1) and the occurrence of various types of vertebral anomalies. The alignment of some 610,000 sequences obtained through vertebral sequencing (454, Roche) yielded the assembly of roughly 22,000 contigs (Figure 2). Analysis of these results will be used to build the first reference gene catalogue and to characterize genes specific to bone tissue. Quantifying the expression of these genes through sequencing (HiSeq2000, Illumina) will then make it possible to determine which ones are involved in the demineralization process and the development of various types of anomalies. The use of molecular tools will be useful not only in formulating new diets consistent with environmental standards, but also in identifying individuals with lower phosphorus requirements.

JAN. 2011 – DEC. 2013

FUNDED BY: Programme de soutien à des initiatives internationales de recherche et d'innovation (PSIIRI)

CO-FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP); Société de recherche et de développement en aquaculture continentale (SORDAC); NSERC – Programme de bourse FONCER; U. Laval – Programme de bourse du Bureau International

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PROJECT TEAM: Marie-Hélène Deschamps, Claude Robert, Grant Vandenberg (U. Laval)

COLLABORATORS: Dominique Bureau (U. Guelph); Ann Huysseune, Eckhard P. Witten (Universiteit Gent); Arnaud Droit (CHUL, Canada); Jean-Yves Sire (Université Paris 6, France); Chantal Cahu, Dominique Mazurais (IFREMER, France); Kenneth Overturf, Ron Hardy (University of Idaho); Tom Hansen, Anna Wargelius, P.E. Fjelldal (Havforskningsinstituttet, Norway)

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DEVELOPMENT OF STRAINS OF ARCTIC CHARR, BROOK TROUT AND THEIR HYBRIDS CAPABLE OF EFFECTIVELY SYNTHESIZING LINSEED OIL INTO POLYUNSATURATED FATTY ACIDS (OMEGA-3)

Measuring development of Arctic Charr at the rearing facility. *Photo: Pierre U. Blier (UQAR)*

The purpose of the research is to produce the tools and information needed to develop strains of Arctic Charr (*Salvelinus alpinus*), Brook Trout (*S. fontinalis*) and their hybrids that would be highly capable of synthesizing omega-3 from a diet based on vegetable oil (linseed oil).

The development of this type of product represents an undeniable element of economic diversification for this agri-food industry. It would give producers the advantage of lowering production costs while substituting fish oils with vegetable oils. This would also help reduce pressure on wild stocks used in the production of aquaculture feed and thus reflect a vision of sustainable development, and so-called "organic" production.

To this end, the variability of the two enzymes responsible for the desaturation of fatty acids and the synthesis of long-chain omega-3 (i.e., delta-6-desaturase, elongase), will be characterized in three groups following a diet based on animal and vegetable oils. The correlation between the expression (mRNA) of both types of enzyme and the omega-3 concentration will be evaluated. With this information, we will be able to identify the strains or families with the greatest potential for maintaining a good long-chain omega-3 profile from a diet based on vegetable oils. The proposed project is intended to contribute to the sustainable development of aquaculture in Canada.

JAN. 2012 – DEC. 2014

FUNDED BY: NSERC; RAQ

PROJECT LEAD: Pierre U. Blier (UQAR)

PROJECT TEAM: France Dufresne, Bernard-Antonin Dupont Cyr, Véronique Desrosiers, Arianne Savoie (UQAR); Grant Vandenberg (U. Laval); Nathalie Le François , Emiko Wong (Biodôme de Montréal); F. Dupuis (Aquaculture Gaspésie Inc.); M. Cantin (Aquaculture des Monts-de-Bellechasse Inc.)

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DETERMINATION OF GEOSMIN AND 2-METHYLISOBORNEOL CONCENTRATIONS IN RAINBOW TROUT BY *IN-VIVO* SAMPLING USING SOLID PHASE MICROEXTRACTION

The presence of off-flavours in farm-raised fish represents one of the most significant economic problems encountered in aquaculture related to product quality. The presence of undesirable odours or tastes (predominately geosmin and 2-methylisoborneol) in fish may cause a major reduction in the consumption of the products, or make them unsuitable for sale. The main objective of the project is to develop strategies to monitor the occurrence of geosmin and MIB in recirculating aquaculture systems using *in vivo* sampling method.

This will improve the organoleptic quality, the image and the economic value of aquaculture products, which contribute to the development of aquaculture in Canada. This highly-innovative approach (SPME *in vivo* sampling) has a clear potential to generate new knowledge in collaboration with Canadian companies and government organizations, with a high potential to have an industrial impact.

APR. 2012 – NOV. 2012

FUNDED BY: NSERC Strategic Grant **CO-FUNDED BY:** Ontario Ministry of Agriculture, Food and Rural Affairs

PROJECT LEAD: Richard D. Moccia (U. Guelph)

PROJECT TEAM: Janusz Pawlisyn (U. Waterloo); Grant Vandenberg (Laval U.)

COLLABORATORS: Alma Aquaculture Research Station (U. Guelph)

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CORN GLUTEN MEAL AND MUSCLE PIGMENTATION IN RAINBOW TROUT

The characteristic red or pink colour of salmonid fish fillets results from the deposition of carotenoids pigments, mainly astaxanthin, within muscle fibers. This quality trait dramatically influences costumers' perception and willingness to pay. Therefore, in order to satisfy costumers' pigmentation standards, carotenoids pigments must be added in formulated diets since salmonids (salmon and trout) cannot synthesise them *de novo*. Dietary astaxanthin supplementation normally accounts for about 5-20% of total ingredient cost of feed.

Corn gluten meal (CGM), a highly digestible by-product of the corn wet milling process with high protein (60% crude protein) content, is widely included in formulated diets for many different fish species. Anecdotal evidence from aquaculture feed manufacturers suggests that high CGM dietary incorporation levels may negatively affect flesh pigmentation in salmonid fish as a result of its relatively high levels (100-500 ppm) of yellow xanthophyll carotenoids (mainly lutein and zeaxanthin). The main objectives of this project are: 1) to assess the effect of natural occurring yellow carotenoids from CGM on Rainbow Trout muscle pigmentation and astaxanthin deposition; and 2) to develop cost-effective techniques for reducing yellow pigment content of CGM.

MAY 2008 – ONGOING

FUNDED BY: National Science and Engineering Council (NSERC); Ontario Ministry of Natural Resources

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STRATEGY FOR IMPROVING THE BENEFICIAL PROPERTIES OF CULTURED FISH FOR HUMAN HEALTH: INCLUSION OF A NEW VEGETABLE OIL IN THE DIET OF TROUT

Over the next few years, 97% of the world supply of fish oil (FO) will be used in aquaculture feed. Adding vegetable oil to replace some or all of the FO in trout feed does not typically affect growth rate or feed conversion. However, oil derived from plant sources does not contain polyunsaturated fatty acids (i.e., long-chain omega-3 [n-3 LCPUFA]), whose properties are beneficial to heart health in humans. Soybean varieties high in stearidonic acid (SDA) were recently produced and could help the aquaculture industry tackle this problem. Adding soybean oil (SO) high in SDA to trout feed would increase the n-3 LCPUFA content in fish flesh. Consumption of such fish would result in positive indicators for heart health. More specifically, the project objectives are to: 1) document the zootechnical performance of trout fed a diet high in SDA-rich SO; 2) quantify the bioconversion of SDA to n-3 LCPUFA in trout fed a diet based on SDA-rich SO; and 3) characterize the impact of fish consumption on heart health indicators in hamsters.

APR. 2012 – APR. 2015

FUNDED BY: Fonds québécois de la recherche sur la nature et les technologies (FRQNT); Merinov; Société de recherche et de développement en aquaculture continentale (SORDAC); RAQ; PIDDAED

PROJECT LEAD: Grant Vandenberg (U. Laval)

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OPTIMIZATION OF OMEGA-3 CONTENT AND ANTIOXIDANT CAPACITY OF FLESH OF STRAINS OF CULTURED CHARR

The ultimate goal of the project is to develop strains of Arctic Charr, Brook Trout, and their hybrids with a higher content of polyunsaturated fatty acids (omega-3) and high antioxidant capacity. The project will enable us to determine, first and foremost, whether incorporating an exogenous antioxidant (astaxanthin) into the diet of fish will stimulate their endogenous antioxidant defenses and, at the same time, serve as additional protection for the integrity of membrane fatty acids. Secondly, we will be able to determine the organoleptic properties of astaxanthin as well as its effectiveness in improving preservation period of fillets. If a correlation is discovered between the mRNA quantification of antioxidant enzymes, their activity and the omega-3 content of the flesh, this first genetic parameter might prove to be a valuable tool for the industry. It will enable quick and simplified identification of strains and individuals with the best endogenous antioxidant defense capacities and the highest omega-3 content as part of a strategic selection plan. The project is a preliminary step in the establishment of strains from Canada's aquaculture industry recognized as functional food that supports cardiovascular health. This would enhance the nutritional status of fish and could act as a lever for Canada's aquaculture industry.

JAN. 2013 – DEC. 2015

FUNDED BY: Fonds québécois de la recherche sur la nature et les technologies (FQRNT); RAQ

PROJECT LEAD: Pierre U. Blier (UQAR)

PROJECT TEAM: France Dufresne, Véronique Desrosiers, Felix Christen (UQAR); Nathalie Le François (Biodôme de Montréal); Grant Vandenberg (U. Laval); Alain Leclerc (Merinov); Aquaculture Gaspésie Inc.; Aquaculture des Monts-de-Bellechasse Inc.

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EVALUATION OF RATION REDUCTIONS ON THE GROWTH, FEED CONVERSION, PIGMENT RETENTION AND SOMATIC INDICES OF RAINBOW TROUT

In aquaculture, feeding is crucial to viability and success. As a rule, fish farmers rely on feed manufacturers to provide well balanced diets for their operations. While the farmer generally has little input into the composition of the diet, they determine the ration that is offered the fish to promote good growth and minimal waste. Underfeeding results in poor growth and production, while overfeeding results in wastage and water quality deterioration. The ration size is normally calculated as a percentage of the biomass present and feeding charts are widely available for Rainbow Trout. However, it is difficult to predict with any accuracy the exact biomass of the fish to be fed. Furthermore, many physiological factors (size, reproductive condition, social stressors, nutritional requirements, gastro-intestinal evacuation, etc.) and environmental factors (oxygen availability, waste metabolite concentrations, temperature, photoperiod, water velocity, etc.) result in day-to-day variations in appetite and these variations are very difficult to predict. As a result, many trout farmers rely on feeding to near-satiation with modifications being made to allow for ambient environmental conditions to achieve optimal feeding rates (the rate that results in the best growth and feed conversion ratio). Feeding to near-satiation may not be the best strategy utilized, if feed costs and environmental concerns are considered. The use of expensive trout diets would suggest greater financial returns are possible if reduced feeding rates are utilized to maximize the feed conversion rate even at the expense of growth rates.

The objectives of this study is to feed Rainbow Trout varying feeding rates from near-satiation to 67% of near-satiation to determine the effects of reduced daily ration on growth, condition factor, size variation, and feed conversion efficiencies, as well as such economically important processing traits as pigmentation, dress-out yield and fillet yield.

Feed can account for approximately 40–60% of a Rainbow Trout farm's operating costs depending upon the type and size of the farm and the feeding husbandry practices followed. Given this fact, significant cost savings could be realized if the farmer was able to reduce the daily feeding rate without compromising fish health, growth, size variation, pigmentation levels and carcass yield.

FEB. 2012 – DEC. 2012

FUNDED BY: Martin Mills Inc. **CO-FUNDED BY:** Ontario Ministry of Agriculture, Food and Rural Affairs

PROJECT LEAD: Richard Moccia (U. Guelph)

PROJECT TEAM: Mark Wagner (Martin Mills Inc.)

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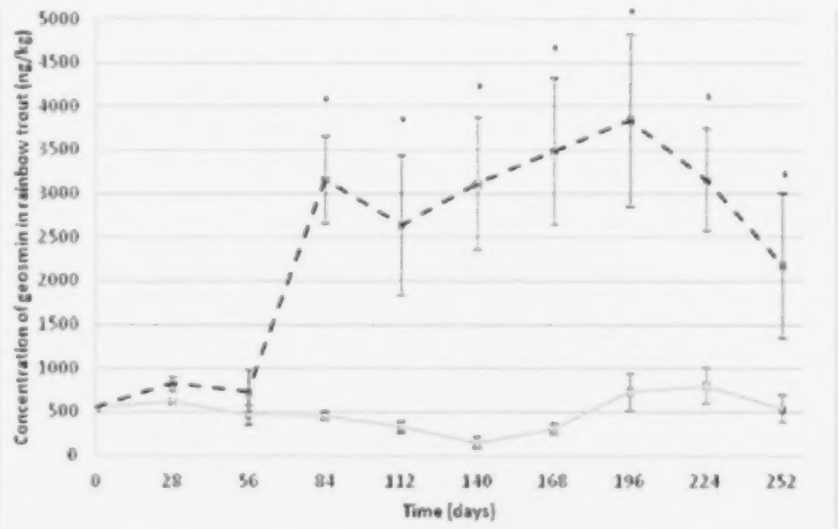
STRATEGIES TO PREVENT OFF-FLAVOURS IN FISH RAISED IN CLOSED-CIRCUIT AQUACULTURE SYSTEM

Geosmin and 2-methylisoborneol have been associated with off-flavour problems in fish and seafood products, generating a strong negative impact for aquaculture industries. Detection of geosmin producers in the fish flesh is normally based on chemical analysis (SPME–GC–MS). However, chemical analysis could not be used to prevent the occurrence of off-flavours. Using a real-time polymerase chain reaction (qPCR) method on water samples, we were able to detect and quantify geoA sequences that encode a germacradienol synthase involved in geosmin synthesis during *Streptomyces* development. To compare the influence of diet on off-flavour development in recirculating aquaculture systems (RAS), Rainbow Trout were fed with two commercial diets (Diet 1: high quality nutrient-dense diet; Diet 2: standard extruded diet known to produce friable feces). We found that the type of diet can influence the performance of Rainbow Trout and the appearance of off-flavour in a RAS. Some parameters such as suspended solids and phosphate concentration were involved in the process of proliferation of geosmin producers. The presence of gene geoA was confirmed much earlier in RAS containing fish fed with diet 2 than diet 1 (56 and 140 days, respectively) and chemical detection of geosmin in trout was observed 28 days after the gene detection. Our results show the advanced capacity of the gene-based method for the early-monitoring of off-flavours in fish reared in RAS.



OCT. 2009 – OCT. 2012

FUNDED BY: NSERC **CO-FUNDED BY:** Institut national de recherche scientifique (INRS); Interprovincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD); RAQ; Société de Recherche et de Développement en Aquaculture Continentale (SORDAC Inc.); PIDDAED

PROJECT LEAD: Richard Villemur (INRS-Institut Armand-Frappier)

PROJECT TEAM: Yves Comeau (École Polytechnique de Montréal); Janusz Pawliszyn, Sanja Risticevic, Ziwei Bai (U. Waterloo); Grant Vandenberg, Alexandre Pilote, Daniel Proulx, Émilie Proulx (U. Laval); Marc Auffret, Karla Vazquez, Roger Dubuc (INRS-IAF)

COLLABORATORS: Kevin K. Schrader (US Dept Agriculture)

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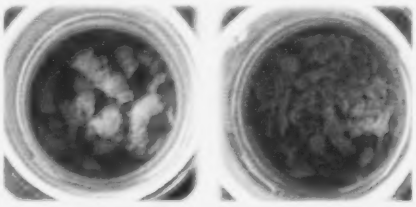

TOP: Concentration of geosmin in Rainbow Trout flesh for the 252 days study period, for Diet 1 (Solid line) and Diet 2 (Dotted line). * = significant difference with $p < 0.05$. Credit: Richard Villemur (INRS). BOTTOM: Trout feces' appearance for Diet 1 (left side) and Diet 2 (right side). Photo: Richard Villemur (INRS)

HISTOLOGICAL OBSERVATIONS ON VERTEBRAL BONE REMODELLING UPON THE APPEARANCE, RECOVERY AND DETERIORATION OF A VERTEBRAL ANOMALY IN CULTURED RAINBOW TROUT FED A DIET LOW IN PHOSPHORUS

Vertebral anomalies are known to be a serious problem in salmonid culture. In 2011, some experiments conducted on juvenile Rainbow Trout showed that a prolonged dietary deficiency of phosphorus over a period of 27 weeks led to the occurrence of vertebral anomalies in most individuals (~90%). One of the factors complicating this type of study is that the appearance of these anomalies is not uniform in all individuals (high phenotypic plasticity). During these experiments, the caudal vertebrae (V31-V47) of trout evolved predominantly in four ways: 1) development and maintenance of a normal phenotype (17%); 2) development and maintenance of biconcave anomalies (16%); 3) development and recovery (from biconcave to normal phenotype, 24%); and 4) development and deterioration (from biconcave to compressed phenotype, 16%). The goal of our study is to identify the cell types found in individuals with extreme phenotypes and to quantify their respective activities in vertebrae having undergone different morphological developments. We will thus have a better understanding of the cellular mechanisms involved in the response to a phosphorus deficiency and their potential roles in vertebral bone remodelling leading to the occurrence of vertebral anomalies.

MAY 2012 – MAY 2014

FUNDED BY: Ministère du Développement économique, de l'Innovation et de l'Exportation (MDEIE) – Programme de soutien aux initiatives internationales de recherche et d'innovation (PSIIRI); DFO – Aquaculture Collaborative Research and Development Program (ACRDP); Société de recherche et de développement en aquaculture continentale (SORDAC); RAQ – Programme de formation orientée vers la nouveauté, la collaboration et l'expérience en recherche (FONCER); U. Laval – Programme de bourse du Bureau International

PROJECT LEAD: Grant Vandenberg (U. Laval)

PROJECT TEAM: Noémie Poirier Stewart, Marie-Hélène Deschamps, Grant W. Vandenberg (U. Laval); Ann Huysseune, Eckhard P. Witten (Universiteit Gent)

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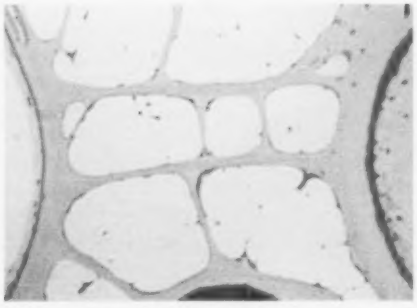

Histological view of the inner part of a salmon vertebrae (*Salmo salar*). Credit: Grant Vandenberg (U. Laval)

STUDY OF THE BROOK TROUT IN TERMS OF THE FUNCTIONAL AND PHYSIOLOGICAL GENOMIC BASES OF PERFORMANCE CHARACTERISTICS, HYBRID VIGOUR AND INTEREST FOR AQUACULTURE

Diversifying and improving the performance of new species used in aquaculture are priorities that will enhance our ability to compete. The Brook Trout is native to eastern Canada, with Quebec as the world's largest Brook Trout producer. The main objectives of this research program were to: 1) clarify the physiological and genomic characteristics of importance for aquaculture production; and 2) document the mechanisms of hybrid vigour and assess its value in Brook Trout production. We developed more than 300 single-nucleotide polymorphism (SNP) genetic markers located in the coding regions of the genome to produce the first genetic map for the Brook Trout. This allowed us to identify quantitative trait loci for characteristics relating to reproduction (sperm concentration and egg diameter), as well as growth and stress response. We also quantified the heritability of growth and stress response, and demonstrated that it varied depending on the strain and the breeding environment. In addition, we demonstrated the occurrence of hybrid vigour in Brook Trout for the first time (up to 88% more growth). However, growth varied depending on the breeding environment and the strains used to make hybrid crosses.

JAN. 2006 – DEC. 2011

FUNDED BY: NSERC; Aquaculture Forestville; RAQ; Société de recherche et de développement en aquaculture continentale (SORDAC)

PROJECT LEADERS: Louis Bernatchez (U. Laval); Céline Audet (UQAR)

PROJECT TEAM: Louis Bernatchez, Nicolas Derôme, Christopher Sauvage, Marie Vagner, Bérénice Bougas, Amélie Crespel, Mathieu Caron, Sarah Granier (U. Laval); Céline Audet (ISMER, UQAR); Daniel Cyr (INRS); Dany Garant (U. Sherbrooke)

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GENETIC AND ECOLOGICAL IMPACTS OF BROOK TROUT STOCKING: ISSUES AFFECTING THE ECOLOGICAL AND ECONOMIC SUSTAINABILITY OF THE AQUACULTURE INDUSTRY IN QUEBEC

The overall objective of this project was to help implement new stocking guidelines put in place by the Quebec Ministère des Ressources naturelles et de la Faune (MRNF), which is responsible for managing the stocking of farmed Brook Trout raised by private producers in Quebec. The guidelines are intended to preserve the genetic integrity of native populations while ensuring the harmonious development of the area as well as the economic and ecological sustainability of the aquaculture and tourism industries, which depend directly on stocking. Given this overall goal, four objectives were targeted. First, we used the latest genomic tools to highlight the extent of adaptive genetic differences between farmed trout and wild trout. Next, we quantified the level of genetic contamination and phenotypic change caused by stocking and showed how the level of genetic changes in wild populations was significantly related to the scope of past stockings and the habitat quality of the water bodies where stockings had taken place. We also showed that introgression of certain domestic alleles of growth-factor genes was accelerated by natural selection in natural populations. Lastly, we developed a predictive model of economic consequences for the aquaculture industry based on the findings and their possible application.

JAN. 2008 – DEC. 2012

FUNDED BY: NSERC – Strategic Subvention

PROJECT TEAM: Louis Bernatchez, Rémy Lambert, Amandine Marie, Fabien Lamaze (U. Laval); Dany Garant (U. Sherbrooke)

COLLABORATORS: Aquaculture Forestville; RAQ; FQGZ, SÉPAQ, MRNF

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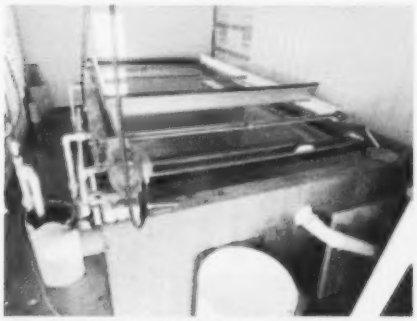
CONSTRUCTION AND EVALUATION OF A NEW SLUDGE AND FLOATING MATERIALS CONCENTRATOR BY USE OF SEDIMENTATION AND MECHANICAL RECUPERATION SUITABLE FOR FISH FARMING



Sludge concentrator. *Photo: André Drapeau (DFO)*

Ferme piscicole des Bobines proposes the construction and evaluation of the effectiveness of a new type of concentrator to reduce the volume of washwater diverted to commercial fish farmers' recirculating accumulation tank. The effectiveness of mechanical treatments involving the use of drum filters currently being used is evaluated at approximately 60 to 65%. These treatments clarify water by continuously removing dumped waste. However, large volumes of water are needed to clean the membrane and it is therefore costly to use in accumulation tanks to filter all water over a long period. This new type of concentrator is innovative in its ability to automatically manage floating materials that form on system surfaces, thereby providing a better ratio of waste concentration. Waste diluted in washwater (400 m^3/d) at the entry of the concentrator will be recovered in concentrated sludge (estimation at 9.6 m^3/d), which will be directed into the accumulation tank. The amount of time that the sludge spends in the accumulation tank will therefore increase from 24 hours to over 20 days.

APR. 2011 – OCT. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Société de recherche et de développement en aquaculture continentale (SORDAC)

PROJECT LEAD: Normand Roy (Ferme Piscicoles des Bobines Inc.)

PROJECT TEAM: Clément Roy (Ferme Piscicoles des Bobines Inc.)

COLLABORATOR: Dominic Marcotte (MAPAQ)

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NANAIMO LAND-BASED STEELHEAD MODEL AQUAFARM

By innovatively applying proven recirculation aquaculture techniques, Taste of BC Aquafarms Inc., in collaboration with PR Aqua Ltd. and Vancouver Island University (VIU), will design and construct a new land-based freshwater production system, based on the concept of the Canadian Model Aqua Farm. This will be the first model farm in British Columbia for stimulating growth in the freshwater aquaculture industry. It will be the first circular tank dual-drain recirculation aquaculture system (RAS) model farm in Canada. Proposed is a novel approach to a production Steelhead farm, incorporating a number of innovations in RAS technology, and innovative operational approaches to a freshwater growout facility.

This farm will be fully operational by the spring of 2013, with a targeted 100 tonne annual production. By incorporating the latest water recirculation technologies, the applicant anticipates a 15% net reduction of overall energy use, and a 20% reduction in total pumping head when compared to existing technology. The project is designed to recirculate almost 98% of system volume, increasing environmental performance by improving water conservation and reducing discharge volume. Furthermore, when combined with the continuous stocking program, the applicant anticipates that it will effectively double the production capacity of the farm.

APR 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** IPSFAD; BC Ministry of Agriculture

PROJECT LEAD: Steve Atkinson (Taste of BC Aquafarms Inc.)

PROJECT TEAM: Janet Atkinson (Taste of BC Aquafarms Inc.); KC Hosler (PR Aqua Supplies Ltd.); Mark Noyon, Don Tillapaugh (VIU); Daniel Stechey (Veridis Aquatic Technologies); Grant Vandenberg (IPSFAD)

COLLABORATOR: PR Aqua Ltd.

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DESIGN AND VALIDATION OF A NEW GENERATION OF REARING POND THAT PERMITS RAPID RECOVERY OF FISH WASTE

The goal of this project was to construct and evaluate a new generation of rearing pond that allows for both water recirculation and the rapid recovery of wastes. To reduce construction costs and optimize waste recovery, the project was carried out in two phases. The aim of the first phase was to model the parameters of the pond using the computational fluid dynamics software Fluent. This made it possible to design and modify the parameters to determine the movement of the waste without having to invest time and money in the construction of one or more pilot units that would require numerous changes or improvements. The aim of the second phase was construction and validation. In combination with the simulation results, an optimally configured pond was constructed. In actual use with cultured fish, this work resulted in an 8% increase in phosphorus recovery. A comparative evaluation of costs concluded that the investment pays for itself in less than 5 years. Although the modelling was performed using a specific rearing unit, the expertise developed for aquaculture could certainly be used in all other Canadian rearing systems.

APR. 2011 – OCT. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Société de recherche et de développement en aquaculture continentale (SORDAC)

PROJECT LEAD: Serge Gilbert (Pisciculture Gilbert)

PROJECT TEAM: Serge Gilbert (Pisciculture Gilbert); France-Line Dionne (l'École Polytechnique de Montréal); Dominic Marcotte (MAPAQ)

COLLABORATORS: Musandji Fuamba, Yves Comeau (Département des génies civil, géologique et des mines de Polytechnique – Université de Montréal)

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Rearing pond with faeces recovery system. *Photo: André Drapeau (DFO)*

THE EFFECT OF DIETARY INTAKE OF PHOSPHORUS ON P STATUS AND BONE METABOLISM OF RAINBOW TROUT

New bone metabolism markers need to be developed to understand the development of skeletal abnormalities resulting from nutritional deficiencies in intensive salmonid culture.

Experiments conducted in 2011 showed that a diet highly deficient in phosphorus (P) does not necessarily affect growth. However, it greatly reduces the P status of fish (blood, scales, carcasses, and vertebrae) as well as the biomechanical performance of the vertebrae, which leads to the occurrence of anomalies in ~ 50% of 5-week-old individuals and ~ 90% of 15-week-old individuals. Despite an increase in the production of circulating hormones (calcitonin and parathyroid hormone-related protein) that stimulate bone mineralization and remodelling in the second week of deficiency, the mechanical stresses and low P levels in the blood lead to the development of spaced, compressed and biconcave vertebrae.

Samples will be analyzed shortly for morphology, histology and genomics. Correlations will help establish the mechanisms involved in the metabolism of phosphorus and bone tissue, as well as the best indicators for preventing the occurrence of vertebral anomalies in the formulation of new more effective and less polluting feed.

JAN. 2011 – DEC. 2013

FUNDED BY: Ministère du Développement économique, de l'Innovation et de l'Exportation (MDEIE) – Programme de soutien aux initiatives internationales de recherche et d'innovation (PSIIRI); DFO – Aquaculture Collaborative Research and Development Program (ACRDP); Société de recherche et de développement en aquaculture continentale (SORDAC); RAQ; FONCER; U. Laval – Programme de bourse du Bureau International

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PROJECT TEAM: Marie-Hélène Deschamps, Nadia Aubin-Horth, Claude Robert (U. Laval); Dominique Bureau (U. Guelph); Ann Huysseune, Eckhard P. Witten (Universiteit Gent); Jean-Yves Sire (Université Paris 6); Chantal Cahu, Dominique Mazurais (IFREMER); Kenneth Overturf, Ron Hardy (U. Idaho); Tom Hansen, Anna Wargelius, P.E. Fjelldal (Havforskningsinstituttet, Norway)

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IMPLEMENTATION OF COMMERCIAL MODE ZOOTECHNICAL MEASURES FOR MAXIMIZING REARING PRODUCTIVITY OF ARCTIC CHARR

The domestication characteristics of the Arctic Charr (*Salvelinus alpinus*), especially its disease resistance, its growth performances at low temperatures, its tolerance to crowding and its association with a high-end market, make it a species with high potential for aquaculture diversification in temperate and northern climates. The emergence of commercial production of this species on a national scale has long been stymied by differences in growth rates and variations in the supply of juveniles of good quality and in sufficient numbers. A 2001 project report makes several recommendations to remedy the situation and promote Canadian aquaculture diversification as a result. Among its recommendations is the development of selective breeding programs focused on improving growth performances and assessing the genetic variability within broodstock populations in major commercial strains. The primary objective of this project is to implement innovative zootechnical measures in terms of the productivity of commercial Arctic Charr aquaculture operations. The recommended measures are aimed at improving reproduction (spawner pairing) and nursery (water velocity) conditions. The specific objectives are: 1) to estimate the genetic variability of available Nauyuk strain in Quebec for possible use in a genetic improvement and a strain development program; 2) to identify, through assessing the level of relatedness between spawners, optimal pairings/crosses based on the work of Ditlecadet *et al.* in 2006 and 2009 and likely to result in growth gains; and 3) to apply, during the initial development stages, an experimental velocity to significantly improve growth.

JUNE 2010 – MAR. 2011

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Aquaculture Gaspésie inc.

PROJECT LEAD: Nathalie Le François (UQAR)

PROJECT TEAM: France Dufresne, Pierre Blier (UQAR)

COLLABORATOR: Francis Dupuis (Aquaculture Gaspésie inc.)

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RESEARCH TO IMPROVE THE QUALITY OF EGGS AND EARLY DEVELOPMENT OF THE YELLOW WALLEYE FOR AQUACULTURE IN QUEBEC

The Yellow Walleye (*Stizostedion vitreum*) is a freshwater fish native to North America. In Canada, its range includes the tributaries of the St. Lawrence River in Quebec. The production of this species is always dependent on the natural environment. Problems associated with egg quality problems as well as embryonic and larval development of eggs from captive brood fish remain a major issue. Experimental trials have shown that eggs from captive brood fish are of lower quality than those from wild brood fish. This problem may be attributable to the brood fish diet. The project aims to improve Yellow Walleye production by developing various kinds of diets for captive brood fish to identify nutritional needs and obtain optimal quality eggs and good embryonic development. An appropriate sampling system will be developed on an industrial site to study the link between brood fish feed, egg quality, embryonic development and larval survival. Batches of eggs from brood fish on different diets will be separated and monitored until the larvae can feed themselves. The project will develop new stock management techniques that will promote strategies leading to greater diversification of fish production in Quebec.

SEP. 2011 – DEC. 2013

FUNDED BY: Société de recherche et de développement en aquaculture continentale (SORDAC); RAQ; Fonds québécois de la recherche sur la nature et les technologies (FQRNT)

PROJECT LEADER: Réjean Tremblay (UQAR)

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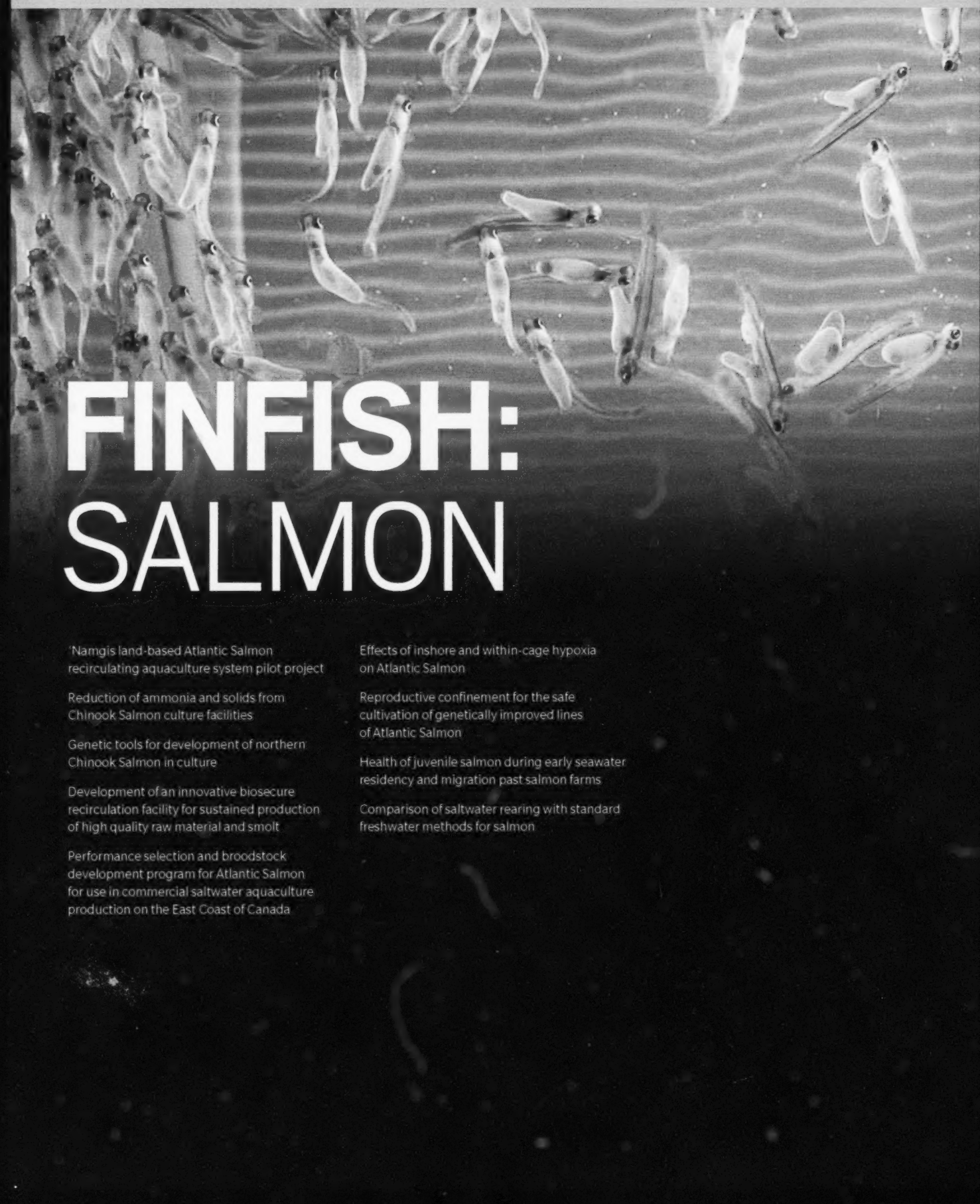
Yellow Walleye captured to be used as brood fish.
Photo: Sahar Mejri



FINFISH: SALMON

'Namgis land-based Atlantic Salmon recirculating aquaculture system pilot project

Reduction of ammonia and solids from Chinook Salmon culture facilities

Genetic tools for development of northern Chinook Salmon in culture

Development of an innovative biosecure recirculation facility for sustained production of high quality raw material and smolt

Performance selection and broodstock development program for Atlantic Salmon for use in commercial saltwater aquaculture production on the East Coast of Canada

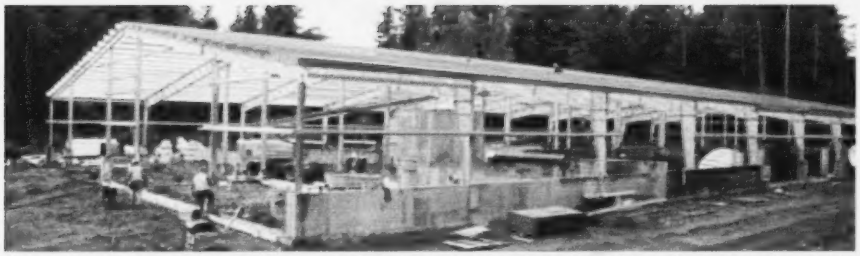
Effects of inshore and within-cage hypoxia on Atlantic Salmon

Reproductive confinement for the safe cultivation of genetically improved lines of Atlantic Salmon

Health of juvenile salmon during early seawater residency and migration past salmon farms

Comparison of saltwater rearing with standard freshwater methods for salmon

'NAMGIS LAND-BASED ATLANTIC SALMON RECIRCULATING AQUACULTURE SYSTEM PILOT PROJECT



'Namgis land-based recirculating aquaculture system under construction. *Photo: Jackie Hildering (K'udas Limited Partnership)*

The 'Namgis Closed Containment Project will produce Atlantic Salmon in a land-based, biosecure, closed containment recirculating aquaculture system (RAS). The SOS Marine Conservation Foundation and Tides Canada are project partners.

The goal of the Project is to evaluate the commercial viability of RAS as an alternative to raising Atlantic Salmon to table-size in net-pens.

The first smolts will enter the facility in January 2013. The first harvest is planned for early 2014.

This project will enable production costs and biological and technical assumptions to be confirmed. The data collected will enable the optimal design and construction of a full-scale (5-module) commercial facility.

Module One will grow-out three cohorts of salmon from smolts (100 g) to market-size salmon (5-6 kg) in commercial scale densities (50 kg/m^3); producing a total of 470 MT of salmon annually. Grow-out trials for this pilot project will continue through 2014.

Project planning and system design was initiated in 2010. AIMAP supported Phase 1 during 2011–12 which completed the system design, finalized performance measurement criteria, acquired key innovative component technologies, and initiated construction.

APR 2011 – MAR. 2012
(Grow-out trials will continue through 2014)

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Tides Canada's Salmon Aquaculture Innovation Fund; Sustainable Development Technology Canada; 'Namgis First Nation; Aboriginal Affairs and Northern Development Canada Coast Sustainability Trust; The Ritchie Foundation; BC Hydro (Power Smart)

PROJECT LEAD: Garry Ullstrom (K'udas Limited Partnership)

PROJECT TEAM: George Speck, Eric Hobson, Robert (Bob) McKenzie, Diane Cornish, Chief Bill Cranmer, Per Heggelund, Catherine Emrick, Andrew Wright, Jackie Hildering (K'udas Limited Partnership Board); Cathal Dinneen (K'udas Limited Partnership)

COLLABORATORS: SOS Marine Conservation Foundation; Tides Canada; The Conservation Fund's Freshwater Institute

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GENETIC TOOLS FOR DEVELOPMENT OF NORTHERN CHINOOK SALMON IN CULTURE

The industry partner, Creative Salmon, maintains a Chinook Salmon strain derived from wild Yukon River Chinook Salmon and samples of cryopreserved milt from wild Yukon males (collected upon strain founding, 1993 – 2004) and 'domesticated' males reared since 1995. We surveyed two year classes of live fish and all cryopreserved milt with twelve microsatellite loci used on wild fish. Stock identification analysis indicated a stock composition of founder fish for the Creative Salmon Yukon strain of 60% Mainstem spawners (closest spawning population to collection site at Minto) and 40% river spawners from Yukon tributaries upstream from Minto.

Individual year classes of domesticated Yukon fish had reduced genetic diversity but a high level of diversity in founder males indicated that the diversity loss occurred during domestication not as a 'founder effect.'

We identified eight polymorphic microsatellite markers to enable cost-effective kinship analysis in northern BC and Yukon Chinook Salmon strains. Analysis of the Creative Salmon Yukon strain indicated that although individual year classes had low diversity, the combined live broodstock (all year classes) and domesticated frozen milt inventory was as diverse as other domesticated strains. A sufficient genetic base exists for an effective pedigreed selective breeding program to improve the Creative Salmon Yukon strain.

APR. 2010 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP)

PROJECT LEAD: Ruth Withler (DFO)

PROJECT TEAM: Janine Supernault (DFO); Barb Cannon (Creative Salmon); Bruce Swift (TriGen Fish Improvement Ltd.)

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REDUCTION OF AMMONIA AND SOLIDS FROM CHINOOK SALMON CULTURE FACILITIES

Metabolic processes in farmed fish, as with all animals, produce wastes. Some of these are nitrogenous, principally ammonia, and they are released into the environment. Increases in nitrogen can occur with a decrease in the efficiency with which feed is utilized by the fish for growth and maintenance. The release of nitrogenous wastes into the environment can have implications for both the ecosystem and for the fish farming facility from which it is being released. Excess nitrogen release represents a potential economic loss in that it is an indication that feed is not being fully utilized by the cultured fish. The excess release can also result in regulatory consequences for culture facilities. Regulators and industry alike are looking for best practices to help reduce the greater levels of these compounds that can be found near farm sites.

This project will explore how feed regimes designed to stimulate *compensatory growth** may be used to reduce nitrogen excretion into the environment during Chinook Salmon production. Adequately exploiting compensatory growth using alternating periods of feed deprivation and re-feeding has the potential to reduce the excretion of nitrogenous wastes from the fish in culture facilities into the environment while increasing better feed utilization by the cultured fish.

**Compensatory growth is the increase in growth that occurs when an animal is fed at normal levels following a period of environmentally-induced slow growth (from feed deprivation, low temperature, exposure to light or photoperiod, etc.). The physiological causes underlying compensatory growth in salmon are not fully understood.*

OCT. 2012 – MAY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** AgriMarine Industries Ltd.

PROJECT LEADS: Ian Forster (DFO); Lawrence Albright (AgriMarine Industries Inc.)

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DEVELOPMENT OF AN INNOVATIVE BIOSECURE RECIRCULATION FACILITY FOR SUSTAINED PRODUCTION OF HIGH QUALITY RAW MATERIAL AND SMOLT

The Newfoundland salmonid aquaculture sector, including Northern Harvest Sea Farms NL Ltd., is reliant upon smolt importations. This negatively impacts competitiveness of Newfoundland-based farms and poses a biosecurity risk by requiring farms to often take delivery of smolt at sub-optimal sizes and times of the year due to the constraints imposed by the logistics of long-distance fish transport.

The project consists of the development of a land-based recirculation technology-based hatchery and broodstock facility with full control of production parameters, temperatures and water chemistry.

The proposed effluent handling system and the structure of the site will be different from current recirculation systems by having ground water used in the recirculation systems returned to ground by first separating the waste products from the discharge. The use of denitrification systems will reduce volumes of discharge water requiring treatment, reduce the amount of organics needed to be filtered out stored and disposed of, and reduce energy requirements through reduced heating. While denitrification systems are in use in aquaculture, they are not used for smolt production and not in North America for this purpose. This approach should materially reduce the environmental footprint of the facility.

APR. 2011 – DEC. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Federal Government (ACOA); NL Government (DFA)

PROJECT LEAD: Aaron Craig (Northern Harvest Sea Farms NL Ltd.)

PROJECT TEAM: John Gale (FracFlow Consultants); Don Downer (Centre of Environmental Excellence)

COLLABORATORS: Fracflow Consultants Inc.; Silk Stevens Ltd.; Centre of Environmental Excellence (Grenfell College, NL)

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Recirculation unit. Photo: Joan Strickland (Northern Harvest Sea Farms NL Ltd.)

EFFECTS OF INSHORE AND WITHIN-CAGE HYPOXIA ON ATLANTIC SALMON

The goal of this project was to determine how reduced oxygen (natural and culture-induced inshore hypoxia) affects Atlantic Salmon growth and immune system function.

The objectives required to achieve this goal were:

To grow Atlantic Salmon post-smolts and older pre-market salmon in the laboratory under reduced oxygen conditions to quantify the effects of hypoxia on growth and metabolic systems (incl. protein and lipid production and quality) over 90 days, simulating farming conditions by controlling for all remaining environmental parameters, stock density and stress.

To challenge Atlantic Salmon post-smolts and older pre-market salmon to ISAv under reduced oxygen tensions. The non-specific and specific immune systems were examined simultaneously establishing how metabolic stress, induced by hypoxia affected disease resistance and immune physiology. The experiment also established vaccine efficacy while the fish was grown under environmental stress. Experiments controlled for all environmental conditions.

SEP. 2009 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Cooke Aquaculture Inc.

PROJECT LEAD: Brian Glebe (DFO)

PROJECT TEAM: John Martell, Steve Leadbeater, Nellie Gagné (DFO); Katja Anttila, Patricia Schulte (UBC)

COLLABORATORS: Keng Pee Ang (Cooke Aquaculture Inc.)

PERFORMANCE SELECTION AND BROODSTOCK DEVELOPMENT PROGRAM FOR ATLANTIC SALMON FOR USE IN COMMERCIAL SALTWATER AQUACULTURE PRODUCTION ON THE EAST COAST OF CANADA

The Atlantic Salmon performance selection and broodstock development program is a multi-element, science/industry collaboration whose general objectives are: 1) to examine genetic variability of traits chosen by industry that will improve commercial viability; 2) to select individuals displaying improvement in those traits; and, 3) to establish a pedigreed line of Atlantic Salmon specifically selected for farming within commercial conditions employed by three Atlantic Canadian fish farming companies (Northern Harvest Sea Farms, Gray Aqua Farms, and Admiral Fish Farms). Genetic variation and heritability for bacterial kidney disease, sea lice, growth, fillet yield and deformities will be studied. This will be completed by: tagging individual fish and conducting challenges; tagging individual fish to create two breeding nuclei that will result in the future broodstock for industry partners; and communal rearing of families in commercial sea cages on farms in New Brunswick and Newfoundland & Labrador for harvest assessment of growth, fillet yield, and incidence of deformities (fish will be assigned parentage by using molecular markers). This program will further increase the potential for traceability by allowing identification of salmon from 'egg to plate'. To date, families have been created for the first two year classes, salmon progeny have been PIT tagged, the initial sea lice challenge completed, the BKD challenge is underway, and various data points have been recorded on each fish over time.

OCT. 2010 – OCT. 2015

FUNDED BY: ACOA – AIF **CO-FUNDED BY:** New Brunswick Innovation Foundation (NBIF)

PROJECT LEAD: Amber Garber (HMSC)

PROJECT TEAM: Susan Hodkinson, Bill Robertson (HMSC); Aaron Craig (Northern Harvest Sea Farms); Robin Muzzerall (Gray Aqua Farms); Chris Rayner (Admiral Fish Farms); Brian Glebe (DFO); Jane Tosh (U. Guelph); Ben Forward, Tony Manning (RPC); Dan MacPhee (Maritime Vet Services); Mike Beattie (NBDAAF)

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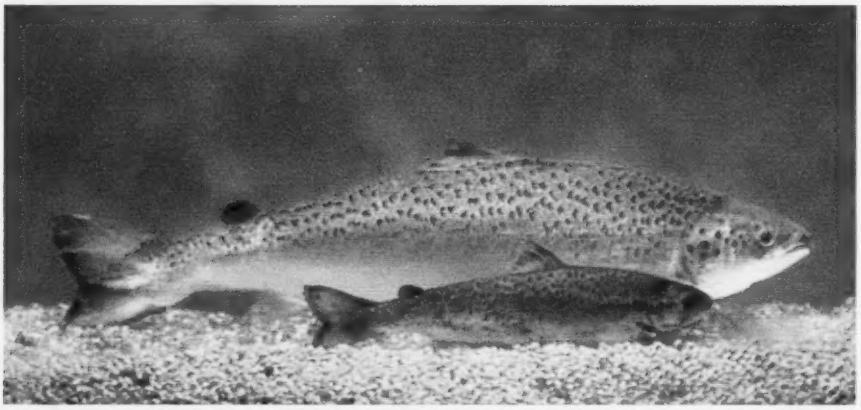
REPRODUCTIVE CONFINEMENT FOR THE SAFE CULTIVATION OF GENETICALLY IMPROVED LINES OF ATLANTIC SALMON



Transgenic vs non-transgenic siblings. Photo: AquaBounty Technologies

There is a general need for the reproductive confinement of aquaculture populations in order to prevent gene flow to wild populations, undesirable colonization of new habitats, loss of energy to gonad development, and protection of intellectual property and proprietary genetics. Reproductive confinement is also a prerequisite for the application of genetic improvement by transgenesis to aquaculture species. Induction of triploidy (addition of one extra set of chromosomes) has been evaluated as a promising approach to sterility, particularly in salmonids. However, the performance of triploids is generally thought to be inferior to that of diploids, their production is labour intensive, and current procedures cannot guarantee 100% of triploidy. Thus, improvements are needed to fully realize the economic potential of sterility relating to the culture of Atlantic Salmon. The ultimate goal of this project is to generate technology, using traditional and genetic selection techniques, which will facilitate the culture of reproductively sterile Atlantic Salmon with performance equivalent to, or better than, the fertile diploid strains currently used. The results of this project will have application to the reproductive confinement of commercial lines of salmon and rapid-growth AquAdvantage transgenic salmon, and will also inform approaches to reproductive confinement of finfish in general.

JAN. 2009 – ONGOING

FUNDED BY: Atlantic Canada Opportunities Agency-Atlantic Innovation Fund (ACOA – AIF) **CO-FUNDED BY:** AquaBounty Technologies; NSERC; Canadian Foundation for Innovation (CFI); Research and Development Corporation (RDC); Innovation PEI; Biotalent Canada

PROJECT LEADS: Debbie Plouffe, Dawn Runighan (AquaBounty Technologies)

PROJECT TEAM: John Buchanan (AquaBounty Technologies)

COLLABORATOR: Tillman Benfey (UNB); Brian Glebe (DFO); Santosh Lall, Darrin Reid, Mike Reith, Sean Tibbetts (NRC); Matt Rise (MUN)

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COMPARISON OF SALTWATER REARING WITH STANDARD FRESHWATER METHODS FOR SALMON

This project will evaluate the effect of different smolt-to-adult rearing environments on the physiology and behaviour of adult salmon. Specifically, salmon caught as out-migrating smolt in Fundy National Park, and then reared in a traditional freshwater hatchery environment (Mactaquac Biodiversity Facility) to adulthood, will be compared with juvenile salmon of the same origin reared for the same duration in saltwater facilities (marine net pens). Following rearing in these two different environments, a suite of biological characteristics relevant to the survival and breeding success of Atlantic Salmon in the wild will be measured and analyzed. This information will help inform managers on the advantages and disadvantages of different rearing strategies for inner Bay of Fundy Atlantic Salmon.

NOV. 2009 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** ACFFA; Parks Canada

PROJECT LEAD: Patrick O'Reilly (DFO)

PROJECT TEAM: Trevor Goff (DFO); Corey Clarke, Renee Wissink (Parks Canada)

COLLABORATOR: Sybil Smith, Caroline Graham (ACFFA)

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HEALTH OF JUVENILE SALMON DURING EARLY SEAWATER RESIDENCY AND MIGRATION PAST SALMON FARMS

Recently, reports have suggested that poor returns of salmon in BC are caused by infections of juvenile salmon with sea lice and other pathogens acquired from salmon farms. There are few data that allow us to understand how and when sea lice infections develop on juvenile salmonids following entry into sea water. In addition, there have been no systematic studies of the overall health of juvenile salmon during their early seawater residency. Without this information it is impossible to predict what, if any, role salmon farms play as a source of sea lice or other pathogens for infection of juvenile wild fish. This project builds upon ongoing collaborative programs between DFO, the aquaculture industry, and the Pacific Salmon Foundation, which are studying several aspects of juvenile salmon health in BC. The overall goals of these programs are to provide the background data necessary to asses what role, if any, salmon farms play as a source of pathogens for wild juvenile salmon. Within the Strait of Georgia and Johnstone Strait, development of sea lice infections on juvenile Pink Salmon, Chum Salmon, and non-salmonid hosts, will be investigated and characterized, yearly for a period of 3 years starting in 2010. Levels of sea lice will be monitored from early seawater entry until the time that the fish enter Queen Charlotte Sound. For Muchalat and Esperanza Inlets increased sampling effort during sea lice surveys will obtain samples of Chum Salmon suitable for histological and microbiological analysis starting in 2011.

OCT. 2010 – MAY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Grieg Seafood BC Ltd.

PROJECT LEAD: Stewart Johnson (DFO)

PROJECT TEAM: Luis Afonso, Sonja Saksida (CAHS)

COLLABORATOR: Barry Milligan (Grieg Seafood BC Ltd.)

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FINFISH: MARINE

Innovations in Atlantic Halibut broodstock conditioning and holding

Development of diet and feeding regimes for Copper Rockfish larvae

Optimization of growth performance in intensively cultured Wolf Eels

Sablefish nutrition research: protein and energy needs

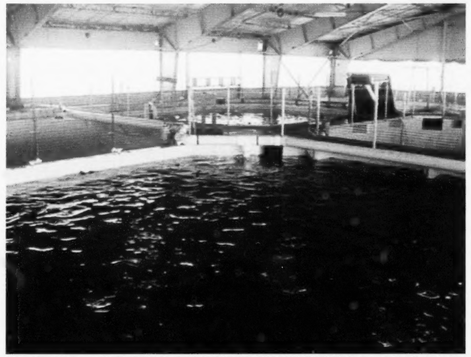
Fertilization strategies for Winter Flounder: Effects of sperm density and the duration of gamete receptivity

Construction and testing of first generation modular system with environmental controls for LIVE transport of Sablefish

The effect of dietary supplementation with zooplankton or fish protein hydrolysate on Atlantic Cod production traits and physiology

Marine hatchery water conditioning module

INNOVATIONS IN ATLANTIC HALIBUT BROODSTOCK CONDITIONING AND HOLDING



Nursery tank system modified for broodstock holding at Scotian Halibut Limited's Woods Harbour facility. *Photo: Carla Dale (DFO)*

Scotian Halibut Limited (SHL) proposes to use innovative broodstock management techniques in order to maximize the growth of their sexually mature fish and therefore shorten the time it takes for them to become effective contributors of gametes for commercial juvenile production. This will require installation of an improved broodstock conditioning/holding system. This system will provide an environment for the cultured broodstock that lets them go through their reproductive cycles with minimum stress but increases the number of degree days available for growth.

SHL intends to build enough tank capacity to hold the stocks selected for integration into the broodstock program which have previously shown signs of reproductive development, such as release of gametes or swelling of ovaries. This represents the first step towards bringing the process of broodstock conditioning to a commercial level. Additional tanks are anticipated to be needed in future years as more of the selected broodstock become sexually mature.

The installation of this system will allow SHL to take advantage of its breeding program in less time than would occur through conventional means. It will allow more rapid availability of domesticated halibut stock for aquaculture which will increase its competitiveness as well as that of its Canadian clients on the global marketplace.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** ACOA – Atlantic Innovation Fund; Nova Scotia Department of Economic and Rural Development

PROJECT LEAD: Brian Blanchard (Scotian Halibut Ltd.)

PROJECT TEAM: Melissa Rommens, Shelley Leblanc, Phillip Nickerson, Peter Corey (Scotian Halibut Ltd.)

COLLABORATORS: Nova Scotia Department of Fisheries and Aquaculture

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DEVELOPMENT OF DIET AND FEEDING REGIMES FOR COPPER ROCKFISH LARVAE

Copper Rockfish, *Sebastes caurinus*, are native to British Columbia and have excellent potential for aquaculture. Previous research (unpublished) has shown that diets with optimal protein:lipid ratios and high DHA content can provide the necessary nutrition to support the culture of Copper Rockfish. In addition, our research has shown that photoperiod manipulation can significantly improve growth performance. There are, however, hatchery production problems that need to be resolved before commercial rockfish aquaculture can be undertaken. In this regard, there is a need to establish reliable protocols for the rearing of larvae from parturition to the juvenile stage. The goal of this research project is to develop a feeding regime for Copper Rockfish larvae that will support good growth performance and survival up to the fry stage.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Totem Sea Farms Inc.

PROJECT LEAD: Ian Forster (DFO)

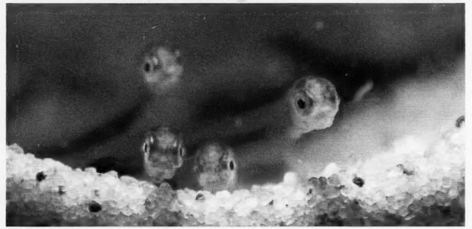
PROJECT TEAM: Shannon Balfry (UBC); Jeff Marlaive (Vancouver Aquarium)

COLLABORATORS: Gus Angus (Totem Sea Farms Inc.)

CONTACT: Ian.Forster@dfo-mpo.gc.ca

Cooper Rockfish female ready to spawn. *Photo: Ian Forster (DFO)*

OPTIMIZATION OF GROWTH PERFORMANCE IN INTENSIVELY CULTURED WOLF EELS



TOP: Wolf Eels in the culture raceway. BOTTOM: Juvenile Wolf Eels. *All Photos: Jonathan Wong (Vancouver Aquarium)*

The Wolf Eels are potential candidates for commercial sustainable aquaculture. Recently, it has been demonstrated that Wolf Eel reproduction can be manipulated with the use of hormone implants, which will aid tremendously in the development of broodstock programs and production timelines. Husbandry protocols, however, need to be developed to establish optimal rearing conditions for Wolf Eels. In this regard, new research has indicated that feeding regimes and rations can be manipulated to optimize growth performance and feed conversion. However, while increasing ration can improve growth rate, feed conversion is not necessarily improved. Additional research studies suggest that a slow gastric evacuation rate may be a contributing factor. Other research aimed at developing husbandry protocols has shown that juvenile Wolf Eels can be raised at very high densities (>40 kg/m^3) without any adverse effects on growth performance or health. Further research is required to develop husbandry protocols that will improve growth and health performance, and determine if an economically viable aquaculture industry for Wolf Eels is feasible.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Island Scallops Ltd.

PROJECT LEAD: Steve MacDonald (DFO)

PROJECT TEAM: Shannon Balfry (UBC); Jeff Marliave (Vancouver Aquarium)

COLLABORATORS: Rob Saunders (Island Scallops Ltd.)

CONTACT: Steve.MacDonald@dfo-mpo.gc.ca

SABLEFISH NUTRITION RESEARCH: PROTEIN AND ENERGY NEEDS

The goal of this project is to provide information for the development of improved feeds for expansion of viable and sustainable aquaculture production of Sablefish in BC. The study consists of three experiments that will provide information concerning: 1) the impact of dietary lipid level on growth rate of sablefish during the "slow-growth" period of 1-1.5 kg; 2) optimize dietary fish oil and fishmeal utilization for growth of this species, as opposed to the use of plant based oils; and 3) reducing the fishmeal in Sablefish grow out diets. Data collection for trials 1 and 3 are continuing, but the results of trial 2 indicated that the best growth of juvenile fish was achieved using very high lipid (approx. 33%) and fishmeal (43%) levels and low carbohydrate. This information is useful to the feed industry to improve production of a high value native food fish.

APR. 2010 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Sable Fish Canada Inc.

PROJECT LEAD: Ian Forster (DFO)

PROJECT TEAM: Mahmoud Rowshandeli (DFO); Jamie Bridge (Sable Fish Canada Inc.)

COLLABORATORS: Briony Campbell (Sable Fish Canada Inc.)

CONTACT: Ian.Forster@dfo-mpo.gc.ca

Sablefish in rearing tank after being fed. *Photo: Ian Forster (DFO)*

FERTILIZATION STRATEGIES FOR WINTER FLOUNDER: EFFECTS OF SPERM DENSITY AND THE DURATION OF GAMETE RECEPTIVITY

LEFT: Winter flounder sperm collection. MIDDLE: Winter Flounder broodstock. RIGHT: Winter Flounder embryos. *All Photos: Ian Butts (U. Windsor)*

Winter Flounder is one of the most commonly used models for studying fish biology in North America; however, little is known about their reproductive ecology, especially during the spawning event. The objectives of this research were to determine the optimal number of spermatozoa required to fertilize eggs and explore how long spermatozoa (30-240 s post-activation) and eggs (30-7680 s post-activation) are receptive to fertilization after exposure to seawater. We conducted experiments using gametes from wild-caught fish and measured fertilization success by examining eggs at 5-6 days post-fertilization. On average 34,038 sperm cells per egg were required to fertilize 81.3% of the eggs. Duration after spermatozoa activation had an effect on the proportion of eggs fertilized. At 30 s post-spermatozoa activation 98% of the eggs were fertilized. After 60 s, a significant decrease in fertilization success was detected. Duration following egg exposure to seawater had an effect on the proportion of eggs fertilized. Between 30 and 1920 s after exposure to seawater the percentage of eggs fertilized ranged from 61 to 90%. A significant decrease to 11% occurred at 3840 s after egg exposure. These results will have implications for optimizing fertilization protocols for hatchery production and management of sperm banks.

JAN. 2006 – JAN. 2012

FUNDED BY: NSERC; AquaNet; New Brunswick Innovation Fund (NBIF); NB Ministry of Research and Innovation
CO-FUNDED BY: George Guptill (Bayshore Lobster Ltd.)

PROJECT LEAD: Ian A.E. Butts (U. Windsor)

PROJECT TEAM: Paymon Roustaian (UNB); Matthew Litvak (Mount Allison University)

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CONSTRUCTION AND TESTING OF FIRST GENERATION MODULAR SYSTEM WITH ENVIRONMENTAL CONTROLS FOR LIVE TRANSPORT OF SABLEFISH

Sable Fish Canada will design, construct, and test an innovative, modular, environmentally controlled transportation system specifically designed for Sablefish and suitable for other aquaculture species with minor modifications. For Sablefish, this project will address the losses incurred during transportation of both juveniles from the hatchery to the farm and larger fish for the live fish market in the lower mainland and abroad.

The biological and environmental requirements of Sablefish are much different than those of Atlantic Salmon. Using systems developed for Atlantic and Pacific Salmon species, juvenile Sablefish transport mortalities averaged 10% in 2010 and were sometimes much higher. The live market transport mortalities can be up to 100%. Mortalities were all due to lack of control over key environmental parameters or equipment failure during transportation.

This project will construct and test an innovative modular environmentally-controlled transport system specifically designed for Sablefish. The system will reduce transport mortality for juveniles to less than 3% and eliminate transport mortality of larger fish to the live market. In addition, the transport system will allow for access to new markets and increase of exports to Asia. Without development of this system, it would be very difficult to increase production or maintain sustainability in the industry.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Bruce Morton (Sable Fish Canada Inc.)

PROJECT TEAM: Briony Campbell, Jamie Bridge, Terry Brooks (Sable Fish Canada Inc.); Linda Hiemstra (Mel Mor Science); Brad Hicks (Taplow Feeds); Eric MacGregor (Versatile Refrigeration); Kan Ogata (Aquamarine Global Seafood Distribution)

COLLABORATORS: BC Sustainable Sablefish Association; Aquamarine Global Seafood Distribution

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THE EFFECT OF DIETARY SUPPLEMENTATION WITH ZOOPLANKTON OR FISH PROTEIN HYDROLYSATE ON ATLANTIC COD PRODUCTION TRAITS AND PHYSIOLOGY

It is not known how/why feeding zooplankton *vs* rotifers/*Artemia*, or adding protein hydrolysate to larval diets, improves cod growth performance. To address this issue, a large multi-disciplinary project titled: "Diet and the Early Development of Atlantic Cod" is currently being conducted. This MSc thesis research is a component of the above project and examines the effects of partial diet supplementation with zooplankton and fish protein hydrolysate on cod production traits (growth, survival, deformities) and how growth relates to the cod's physiology (i.e., metabolism and stress response) and the expression of growth and appetite regulating genes.

Atlantic Cod larvae were fed 3 different diets: enriched rotifers/*Artemia* (RA); RA + fish protein hydrolysate (RA-PH) 3 days per week until weaning; and RA supplemented with 5 — 10% wild caught zooplankton (RA-Zoo) until 30 dph (days post-hatch).

Cod from the RA-Zoo group were 31% heavier at 190 dph, and this was primarily due to accelerated growth (by approx. 2% day $^{-1}$) during the early developmental stages (0 — 60 days post-hatch). In contrast, growth in the RA-PH group was similar to the RA group but with lower survival and the highest incidence of deformities (primarily lordosis). Metabolic parameters (resting and maximum metabolic rate and metabolic scope), and pre- and post-stress cortisol levels were similar in juvenile cod from the RA and RA-Zoo groups. The absence of a treatment effect on juvenile physiology is consistent with the lack of a growth rate advantage in the RA-Zoo group during this period. The effects of the various diets on growth- and appetite-related gene expression are currently being examined.

Our results indicate that: 1) 5 — 10% supplementation with zooplankton can significantly increase the growth rate of cod, but that this accelerated growth is limited to the larval period; and 2) not all protein hydrolysate formulations have beneficial effects on fish growth performance.

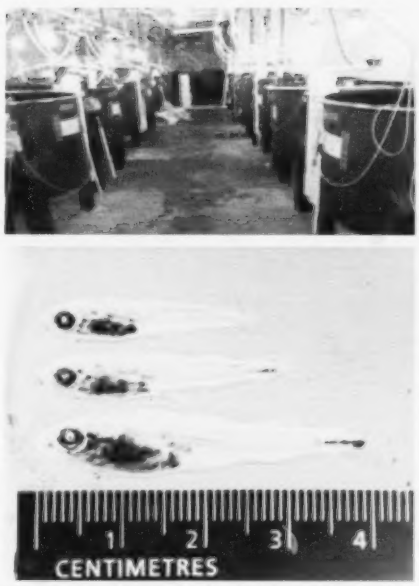
SEP. 2011 - MAR. 2014

FUNDED BY: Atlantic Canada Opportunities Agency (ACOA); Research & Development Corporation of Newfoundland and Labrador (RDC); Newfoundland Cod Broodstock Company

PROJECT LEAD: Tomer Katan (MUN)

PROJECT TEAM: Kurt Gamperl, Chris Parrish, Matthew Rise, Gordon Nash (MUN); Danny Boyce (OSC)

CONTACT: tkatan@mun.ca, kgamperl@mun.ca



TOP: Experimental tanks at the Joe Brown Aquatic Research Building. *Photo: Tomer Katan (MUN)*

BOTTOM: Representative fish from the 3 groups at 60 dph (from top to bottom: RA-PH, RA and RA-Zoo). *Photo: Tomer Katan (MUN)*

MARINE HATCHERY WATER CONDITIONING MODULE

Marine Hatchery Water Conditioning Module (water chiller, monitoring and control panel, alarms, reverse osmosis equipment). *Photo: Linda Hiemstra (Sable Fish Canada Ltd.)*

Sable Fish Canada Ltd. was awarded $200,000 in AIMAP funding to help build a Marine Hatchery Water Conditioning Module for the purpose of controlling temperature and salinity of hatchery culture water, recovering waste heat generated by a chiller, and recycling used incubation water. Slight fluctuations in temperature and salinity from optimal conditions are known to cause deformities and mortalities in juvenile fish. This innovative project constructed and implemented a novel system that delivers precise temperature and salinity conditions improving hatchery culture conditions, reducing deformities, and reducing mortalities.

This innovative equipment delivers water of various salinity levels and temperatures 24 hours a day seven days a week with 100% reliability. This project designed and tested the novel system which delivered a 50% reduction in deformities by better controlling the optimal culture environment and utilizing energy efficient technologies. Sable Fish Canada Ltd. believe this technology has good potential to become an industry standard for all new marine fish hatcheries.

Beyond Sable Fish Canada Ltd., development of the Marine Hatchery Water Conditioning Module has created an opportunity to commercialize and market the cutting edge technology globally.

APR 2011 - MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Bruce Morton (Sable Fish Canada Ltd.)

PROJECT TEAM: Jamie Bridge, Briony Campbell, Tom Schultz (Sable Fish Canada Ltd.)

COLLABORATOR: Kyuquot Checleseht First Nations

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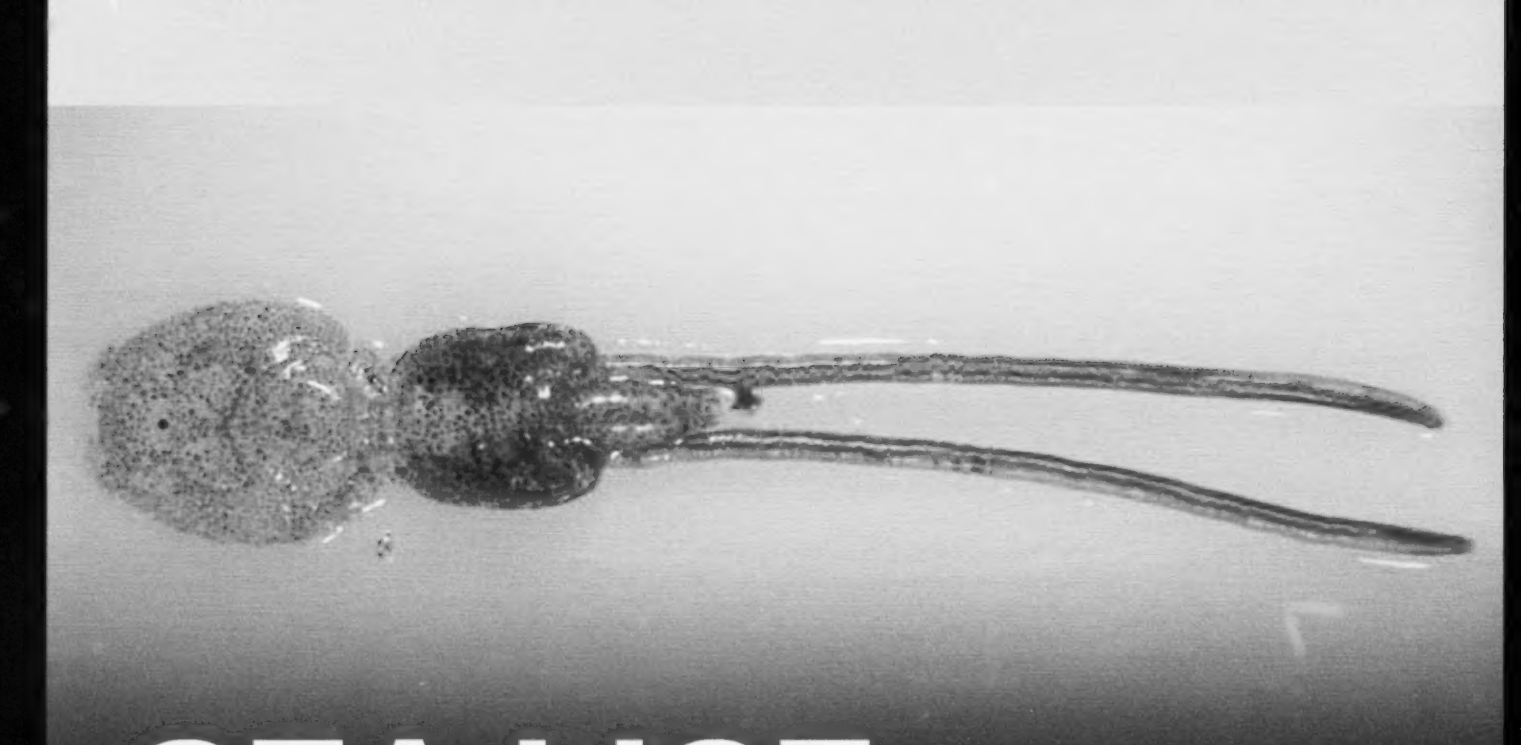

SEA LICE

Development and assessment of a sea lice removal system for farmed salmon

Can sea lice carry and transmit bacterial and viral pathogens to salmon?

Monitoring and modelling of sea lice interaction with wild and farm salmon in the Broughton Archipelago

Refinement of the principles of larval sea lice capture using a combination of biological filters and physical light traps in a commercial setting

Utilization of the Cunner, a wrasse, as a means for sea lice removal in commercial salmon farms

Detecting SNP association with resistance to sea lice in Atlantic Salmon

Field testing "green-technology" sea lice traps and documenting on-site dynamics of sea lice early life history

Sea lice vaccines for salmonid aquaculture

Potential of using Cunners to control sea lice infestation of Atlantic Salmon in Newfoundland

Evaluation of the efficiency of non-chemical methods to reduce the impact of sea lice associated with salmon aquaculture sites using the principles of bio-filtration and trapping

Cumulative impacts, kinetics and tissue distribution of anti- sea lice pesticides in non-target organisms

The Broughton Archipelago Management Plan (BAMP) in British Columbia

Tools to resolve environmental impacts and treatment resistance in sea lice — 2 (TREAT2)

DEVELOPMENT AND ASSESSMENT OF A SEA LICE REMOVAL SYSTEM FOR FARMED SALMON

During the sea water production cycle, farmed Atlantic Salmon (*Salmo salar*) sometimes get infected with sea lice — most often *Lepeophtheirus salmonis*, a naturally occurring parasite in the north Pacific region. A costly chemical therapeutant is the most common treatment used. Fish pumps and airlift systems for grading and moving farmed fish are used routinely in aquaculture. However, modification of these types of systems specifically for the removal of sea lice is novel. The primary objective of this pilot project is to: 1) incorporate modifications to existing 'grading' systems to produce an effective mechanical sea lice removal and collection system; and 2) to assess the new system in the field under normal production conditions.

In summary, the study showed that mechanical removal of sea lice by water jets built into an industry-standard grading device may be a valuable tool in managing sea lice. The initial prototypes were able to remove all stages of sea lice with little to no scale damage to the fish and did not result in any change in mortality but were not effective in reducing the sea lice levels significantly below the threshold levels required to eliminate the need for chemical treatment. A subsequent prototype marginally achieved the threshold level of reduction, suggesting that further modifications may result in more effective removal.

NOV. 2011 – FEB. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Diversified Aquaculture Inc.; Smith Marine Services; Grieg Seafood BC Ltd.; Centre for Aquatic Health Sciences (BC CAHS)

PROJECT LEAD: Odd Grydeland (Diversified Aquaculture Inc.)

PROJECT TEAM: Henrik Kreiberg (DFO); Daryl Smith (Smith Marine Services); Sonja Saksida (BC CAHS); Barry Milligan (Grieg Seafood BC Ltd.)

CONTACT: Odd2@shaw.ca

Barnes Bay sea lice removal. Photo: Odd Grydeland (Diversified Aquaculture Inc.)

CAN SEA LICE CARRY AND TRANSMIT BACTERIAL AND VIRAL PATHOGENS TO SALMON?

Inoculating a plate with sample material. Photo: Duane Barker (VIU)

The role of ectoparasitic sea lice in disease propagation (as a possible vector) or progression (impacts on the host's immunology) has not been described. Our research has been conducted in two phases: 1) experimental testing of the vector potential of sea lice — acquisition and transfer of bacteria (*Aeromonas salmonicida*) or infectious haematopoietic necrosis virus (IHNV) between salmon; and 2) examination of the changes (genetic and cellular) in immune response of salmon skin as a result of sea lice feeding. Our results demonstrated sea lice can acquire the bacterium, *Aeromonas salmonicida* or virus (IHNV) from a water bath or from feeding on infected salmon. They can then transfer that bacterium or virus to uninfected fish. However, successful transfer only occurred when three conditions were present: very high concentration of pathogen (higher than found in nature), very low water dilution and young salmon (< 200 g) as hosts. Furthermore, the virus and bacteria remain associated with sea lice for limited duration, 24 and 120 h, respectively. Thus, the probability of sea lice transferring these pathogens among salmon under natural settings is extremely low. Our immunological research demonstrated significant differences in the response of key immune associated genes in the skin of three salmon species (Atlantic, Pink, and Chum) when infected by sea lice. Sea lice secretions affect various components of a fish's immune system. At a genetic level, gene expression (i.e., genes turned "on") is enhanced among resistant fish (e.g., Pink Salmon); whereas, more susceptible species (e.g., Atlantic Salmon) show depressed immune gene activity (i.e., genes are turned "off" or blocked). Similarly, at the cellular level, the function of key immune cells (macrophages) was impaired among susceptible salmon (Atlantic and Chum), but not among resistant species (Pink). As a final note, we are quite pleased that this project involved considerable student training; 1 post-doctoral fellow, 3 graduate, and 9 undergraduate students.

MAY 2009 – AUG. 2012

FUNDED BY: NSERC Strategic Grant **CO-FUNDED BY:** DFO; Marine Harvest Canada; Centre for Shellfish Research (VIU)

PROJECT LEAD: Duane Barker (VIU)

PROJECT TEAM: Eva Jakob, Laura Braden, Colin Novak, Danielle Lewis (VIU); Simon Jones, Kyle Garver, Stewart Johnson (DFO); Diane Morrison, Brad Boyce (Marine Harvest, Canada); Ben Koop (UVic); Scott McKinley (UBC)

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MONITORING AND MODELLING OF SEA LICE INTERACTION WITH WILD AND FARM SALMON IN THE BROUGHTON ARCHIPELAGO

The interaction of sea lice with farmed salmon and wild salmon has been the focus of international concern for at least a decade. Health and growth performance issues associated with sea lice infestations continue to be a significant concern for the salmon farming industry globally, driving the implementation of preventative measures in areas where there is the threat of infestation. Since 2003 British Columbia salmon farming industry had been monitoring and reporting sea lice information to government authorities as part of a broader program known as the Provincial Sea Lice Management Strategy, and more recently, in accordance with licensing conditions. In addition to regular monitoring, treatment trigger levels were established in 2003 which are comparable to other international jurisdictions. Concurrently with this management strategy, ten years of intensive research evaluating the effects of farmed-derived sea lice on wild salmon have resulted in a substantial improvement of our knowledge of sea lice biology (genetics, life history, distribution, abundances, and tolerances) and of the susceptibility and resistance of salmonids to sea lice. This project will develop a predictive model of the distribution of sea lice originating from fish farms and estimate the number of encounters of out-migrating salmon with sea lice. It will also establish statistically robust models that capture associations between the sea lice burden on wild fish and conditions on BC fish farms. Finally, the project will monitor the presence of sea lice during the 2012 out-migration of juvenile salmon.

JULY 2012 – MAY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Marine Harvest Canada, Mainstream Canada Ltd.; Grieg Seafood BC Ltd.

PROJECT LEAD: Peter Chandler (DFO)

PROJECT TEAM: Mike Foreman (DFO); Crawford Revie (UPEI); Martin Krkošek (U of T)

COLLABORATORS: Diane Morrison (Marine Harvest Canada); Barry Milligan (Mainstream Canada Ltd.); Peter McKenzie (Grieg Seafood BC Ltd.)

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UTILIZATION OF THE CUNNER, A WRASSE, AS A MEANS FOR SEA LICE REMOVAL IN COMMERCIAL SALMON FARMS

The control of sea lice infestations among populations of farmed salmon in Atlantic Canada has become increasingly difficult over the past years. Farming companies globally find themselves in a position where they have limited abilities to combat sea lice and are now using emergency bath-type pesticide treatments to control infections.

One method of sea lice control deserving of a thorough investigation is the use of wrasse or cleaner fish. With this type of approach, wrasse are placed directly in the sea cages with the farmed salmon and these fish are predicted to consume the sea lice off the salmon. If proven to be practical, the use of wrasse would be a novel sea lice control approach as it would be an environmentally friendly and natural biological tool.

The objectives of this project are: to study the behaviour of Cunners, a wrasse, and their interactions with salmon and vice versa, and to determine if Cunners will consume feed pellets for salmon (feed preference tests) through tank trials; and to test the effectiveness of Cunners as cleaner fish in commercial sea cages.

SEP. 2011 – OCT. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** New Brunswick Department of Agriculture, Aquaculture and Fisheries (NB DAAF)

PROJECT LEAD: Keng Pee Ang (Kelly Cove Salmon Ltd.)

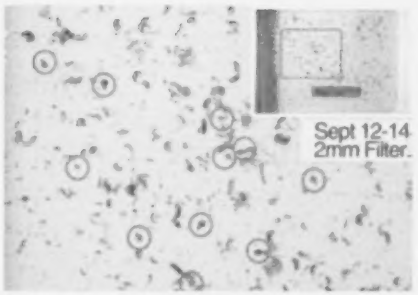
PROJECT TEAM: Frank Powell, Peter Groom, Leighanne Hawkins, Randy Griffin, Nell Halse (Kelly Cove Salmon Ltd.); Shawn Robinson (DFO)

COLLABORATORS: Per Gunnar Kvenseth (Villa Organic AS – Norway)

CONTACT: keng.pee.ang@cookeaqua.com

Transferring Cunners into a cage. *Photo: Keng Pee Ang (Kelly Cove Salmon Ltd.)*

REFINEMENT OF THE PRINCIPLES OF LARVAL SEA LICE CAPTURE USING A COMBINATION OF BIOLOGICAL FILTERS AND PHYSICAL LIGHT TRAPS IN A COMMERCIAL SETTING



Zooplankton captured using the light trap (sea lice pre-adults are circled. *Photo: Shawn Robinson (DFO)*

Sea lice, *Lepeophtheirus salmonis*, are an endemic ectoparasite that can cause direct physical damage to fish and incur huge treatment costs for the aquaculture industry. Chemo-therapeutants and animal husbandry practices have traditionally been used to keep the parasites under control. However, the control of sea lice infestations among populations of farmed salmon in Atlantic Canada has become increasingly difficult over the past two years with the summer of 2010 being the worst on record in certain areas of New Brunswick. The industry has an immediate need for an integrated pest control/management strategy that relies on multiple approaches for sea lice control. This project will expand on previous ACRDP research on the ability of mussels to act as a bio-filter to remove sea lice from an environment, and will assess the ability of various types of sea lice traps to collect sea lice for removal from a cage culture environment. Previous lab findings will be tested in field situations prior to advancing to the commercialization stage.

MAY 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

PROJECT LEAD: Shawn Robinson (DFO)

PROJECT TEAM: Andrea Bartsch (DFO)

COLLABORATORS: Keng Pee Ang, Frank Powell (Kelly Cove Salmon Ltd.)

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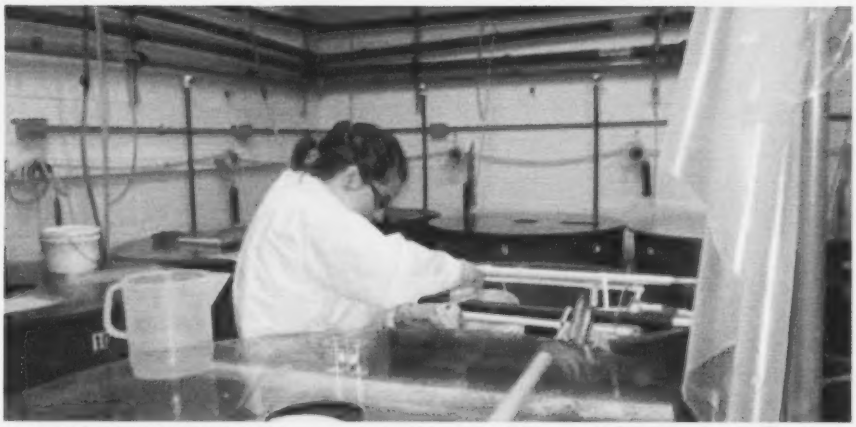
DETECTING SNP ASSOCIATION WITH RESISTANCE TO SEA LICE IN ATLANTIC SALMON



Lab sampling. *Photo: S. Leadbeater (DFO)*

Developing breeds of Atlantic Salmon (*Salmo salar*) that are more resistant to sea lice (*Lepeophtheirus salmonis*) could benefit the Canadian aquaculture industry. Sea lice resistance is typically measured on the relatives of potential broodstock making it difficult to select for in a traditional breeding program. In the future, marker-assisted selection could increase the rate of genetic improvement in sea lice resistance. Our work involves genotyping candidate broodstock and their relatives using DNA markers called single nucleotide polymorphisms (SNPs). Our initial objective is to detect associations between 6000 SNPs and resistance to sea lice in the Saint John aquacultural strain of Atlantic Salmon.

We are measuring resistance by challenging recent smolts with sea lice and then recording the number of sea lice found on each fish. Parents of those fish are genotyped for the 6000 SNPs. We will analyze the data to detect associations of resistance in offspring to SNP genotypes of their parents.

Preliminary results for sea lice challenges in 2011 show some SNP associations with resistance in fish. This is promising for our study and suggests that in the future, resistance could be successfully included in North American Atlantic Salmon breeding programs using marker-assisted selection.

SEPT. 2009 – SEPT. 2013

FUNDED BY: NSERC Strategic Project Grant

PROJECT LEAD: Elizabeth Boulding (U. Guelph)

PROJECT TEAM: Christina Rochus, Larry R. Schaeffer, Jane Tosh (U. Guelph); Keng P. Ang (Cooke Aquaculture Inc.); Brian Glebe, Steven Leadbeater (DFO)

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SEA LICE VACCINES FOR SALMONID AQUACULTURE

Sea lice infestations present a significant challenge to aquaculturists, veterinary clinicians, and vaccine developers. Recent R&D at Pfizer Animal Health (Pfizer Canada Inc.) has identified a set of vaccine candidates. The goal of this project was to complete the remaining development, pre-commercial manufacturing, and regulatory work required to license a vaccine for the control of sea lice infestations of farmed salmon in Canada.

Over the past year, the candidate vaccine antigens were tested. However, the trial results did not show significant reduction in the vaccinated groups.

Pfizer Inc. understands how important a sea lice vaccine is to Canada and to the international aquaculture community. As a result, they are fully committed to this project and continue to work toward proving efficacy and obtaining all related Canadian regulatory approvals.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Fisheries & Oceans Canada (Science Sector); British Columbia Ministry of Agriculture

PROJECT LEAD: Jan Burian (Pfizer Canada)

PROJECT TEAM: Elizabeth Crump, David Asper, Kyle Clarke (Pfizer Canada Inc.)

COLLABORATORS: Fundacion de Chile; St. Andrews Biological Station (DFO)

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FIELD TESTING "GREEN-TECHNOLOGY" SEA LICE TRAPS AND DOCUMENTING ON-SITE DYNAMICS OF SEA LICE EARLY LIFE HISTORY

The sea louse, *Lepeophtheirus salmonis*, continues to be a global problem for salmon farming operations. Chemo-therapeutants and animal husbandry practices have been used to keep the parasites under control, however, studies have indicated that sea lice are starting to become resistant to therapeutants with continued exposure. There is also concern over the impacts of therapeutants upon the ecosystem in which they are being used. Additionally, operational practices at farm sites could be contributing to the magnification of sea lice infections on the salmon if control measures are not being used throughout all sea lice life stages (e.g., eggs) thereby allowing the parasite to continue to breed more successfully. A more integrated approach to pest management, including the use of alternative (non-chemical) treatments, would be helpful in supplementing chemical treatments and preventative husbandry practices. Light-based traps are considered an additional (non-chemical) treatment method. In this particular study, traps were demonstrated in laboratory trials to significantly increase the removal rate of sea lice larvae from the water column, as larvae (both nauplii and copepodites) responded strongly to light. This project will field test the concept that physical light-based traps, in conjunction with an understanding of the on-site sea lice larval dynamics, can play a role in helping to control sea lice populations. It will also analyze and refine the effectiveness of the traps to specifically target sea lice and minimize the capture of non-target species.

AUG. 2012 – MAY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

PROJECT LEAD: Shawn Robinson (DFO)

COLLABORATORS: Keng Pee Ang, Frank Powell (Kelly Cove Salmon Ltd.)

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POTENTIAL OF USING CUNNERS TO CONTROL SEA LICE INFESTATION OF ATLANTIC SALMON IN NEWFOUNDLAND

In most salmon farming countries, prolonged use of chemical therapeutants (e.g., SLICE®) to control sea lice (*Lepeophtheirus salmonis*) infestation has led to the emergence of resistance in some local sea lice populations. The use of cleaner fish (e.g., wrasse species) to remove sea lice from Atlantic Salmon in cages has been developed and utilized in Europe with some success and has been considered in Canada (NB) (i.e., through the use of the wrasse-like Cunner). However, many questions still remain unanswered regarding the success of this alternative method of sea lice control in this country and in particular in Newfoundland (Cunner stock differences in effectiveness; species fitness; geographical differences in seasonal effectiveness in active cleaning, among others). It is the goal of this project to use local Newfoundland populations of Cunners as potential cleaner fish and evaluate feeding behaviour on sea lice by comparing stocks and fish sizes. This project will bring relevant information on the potential application of Cunners to control sea lice in salmon cages in Newfoundland.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon Inc. – Cooke Aquaculture Inc.

PROJECT LEAD: Dounia Hamoutene, Harry Murray (DFO)

PROJECT TEAM: Danny Boyce (MUN); Danny Ings, Lynn Lush, Kim Hobbs, Juan Perez-Casanova (DFO)

COLLABORATORS: Keng Pee Ang (Cold Ocean Salmon Inc. – Cooke Aquaculture Inc.)

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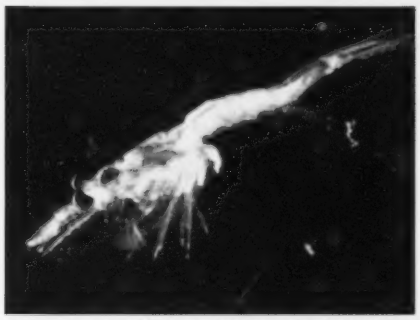
CUMULATIVE IMPACTS, KINETICS AND TISSUE DISTRIBUTION OF ANTI-SEA LICE PESTICIDES IN NON-TARGET ORGANISMS

This research uses oxidative stress biomarkers to assess the sublethal and cumulative impacts of sea lice treatments (AlphaMax® [deltamethrin] and Salmosan® [azamethiphos]) on non-target organisms. Kinetic studies will be conducted to assess the bioaccumulation rate and persistence of AlphaMax® in shrimp and lobster tissue. Damage caused by oxidative stress (lipid and protein oxidation) will be assessed after exposing shrimp and lobster to Salmosan® in the laboratory for long periods of time. The connection between this biochemical damage, histological lesions and resistance to stress will be assessed in adult lobster. Bioaccumulation speed and tissue distribution in shrimp and lobster will be assessed using macroautoradiography and high-performance liquid chromatography coupled with flow scintillation counting (HPLC-FSC) at environmentally-realistic doses by using in-house synthesized ^{14}C deltamethrin. Macroautoradiography is a nuclear technique used to quantitatively determine the distribution of a chemical product labelled with a radioactive atom such as ^{14}C in thin cryosections (0.05 mm) of an entire animal. Preliminary work will also be conducted before assessing the bioavailability of deltamethrin adsorbed in suspended particulate that settles at the bottom.



Opossum shrimp (Mysis sp.). *Photo: Jean-François St-Pierre (DFO)*

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT LEAD: Catherine Couillard (DFO)

PROJECT TEAM: Claude Rouleau, Benoît Légaré (DFO)

COLLABORATORS: L. Burridge, Andrew Cooper, Susan Waddy (DFO)

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EVALUATION OF THE EFFICIENCY OF NON-CHEMICAL METHODS TO REDUCE THE IMPACT OF SEA LICE ASSOCIATED WITH SALMON AQUACULTURE SITES USING THE PRINCIPLES OF BIO-FILTRATION AND TRAPPING

Blue Mussel. *Photo: DFO*

This project seeks to provide the proof of concept information from laboratory research that is required to advance to the next stage, which is to evaluate the feasibility of non-chemical methods for the control of sea lice as part of an overall integrated farm health management plan. Specifically, there are two objectives: 1) to evaluate the effectiveness of the Blue Mussel (*Mytilus edulis*) in removing sea lice nauplii from the water column (evaluation of the removal efficiency will be performed via gut content analysis of the mussels using recently developed PCR-based techniques); and 2) to test the behavioural responses of sea lice to a number of established cues on light, colour, motion, and chemical attractants in various combinations. Once a suitable combination is found, a prototype will be made and tested in comparison to an existing trap from the West Coast.

AUG. 2010 – MAR. 2011

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.; Admiral Fish Farms Ltd.

PROJECT LEAD: Shawn Robinson (DFO)

PROJECT TEAM: Ian Bricknell (U. Maine); Andrew Cooper (DFO)

COLLABORATORS: Keng Pee Ang (Kelly Cove Salmon Ltd.); Howard Streight (Admiral Fish Farms Ltd.)

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THE BROUGHTON ARCHIPELAGO MANAGEMENT PLAN (BAMP) IN BRITISH COLUMBIA

LEFT: Beach seining in the Broughton Archipelago. *Photo: Stan Proboszcz (Watershed Watch Salmon Society)* RIGHT: Moresby salmon cage site. *Photo: Marine Harvest Canada Ltd.*

The Broughton Archipelago Management Plan (BAMP), a unique multi-lateral initiative, involving the various stakeholders with an interest in the management of sea lice in British Columbia, was developed to provide a means with which to clarify key scientific findings and ensure their appropriate application to aquaculture production in the region.

BAMP objectives include: coordinating the on-going monitoring of sea lice on juvenile wild salmon through extensive sampling during the spring migration period; facilitating the integration of historical sea lice data collected over the past decade in the Broughton Archipelago by the farming industry, government and independent researchers; comparing spatial patterns and temporal trends of sea lice infestation; and developing models to better predict sea lice transmission and assess the efficacy of different farm and sea lice management strategies.

For each of the spring migration periods from 2010 to 2012, an extensive field programme has been carried out under the auspices of BAMP to determine, among other things, the relative merits of various sampling strategies in assessing levels of sea lice infestation on wild Pacific salmonids and the most efficient way to achieve such assessments. In addition, a virtual research environment has been created to allow for the sharing of various types of data collected over the past decade and the integration of current research data/results to ensure that the models created are calibrated and validated using the most extensive sets of available data.

JAN. 2010 – DEC. 2014

FUNDED BY: Fisheries and Oceans Canada (DFO); Coastal Alliance for Aquaculture Reform (CAAR); Marine Harvest Canada; Mainstream Canada; Grieg Seafood

PROJECT TEAM: Peter Chandler, Mike Foreman, Simon Jones (DFO); Martin Krkošek (U of T); Peter McKenzie (Mainstream Canada); Barry Milligan (Grieg Seafood); Diane Morrison (Marine Harvest Canada); Crawford Revie (UPEI)

COLLABORATORS: Keng Pee Ang (Cold Ocean Salmon Inc. – Cooke Aquaculture Inc.)

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WWW.BAMP.CA

TOOLS TO RESOLVE ENVIRONMENTAL IMPACTS AND TREATMENT RESISTANCE IN SEA LICE – 2 (TREAT2)

Throughout the history of salmon culture, the sea louse (*Lepeophtheirus salmonis*) has been the greatest external threat to the industry's viability. Costing anywhere from 10 – 20% of the landed commercial value of the fish and perhaps more so in the near future (summer/fall 2010), this parasite now threatens the existence of salmon culture in the Atlantic. Over the past few years sea lice populations in Chile, northern Europe, and now New Brunswick, Canada, have begun to exhibit resistance to the in-feed treatment SLICE™-Schering-Plough. Since it was introduced in 2000, SLICE™ was so highly effective that it quickly became the only available treatment used against sea lice in Canada. However, treatment failures were first observed in 2008 and now SLICE™ resistance has completely removed the effective use of the drug in NB. With few treatments for licensing on the horizon, the identification of alternative methods of sea lice control would be extremely beneficial to the health and welfare of cultured salmon, as well as the sustainability of salmonid aquaculture. The TREAT2 project plans to stabilize the external effects of sea lice on salmon culture by getting to the heart of parasitic resistance to treatment and host immune mechanisms, by: 1) identifying key genes and genomic regions important for development of chemical resistance using a SNP chip and genetic map; 2) Carrying out current and new product testing and identifying expression patterns of genes involved in biological processes and pathways in host/parasite interactions; and 3) identifying host susceptibility/resistance and therapeutic responsiveness traits and methods for enhancement.

DEC. 2012 – DEC. 2015

FUNDED BY: ACOA – AIF; Novartis Animal Health **CO-FUNDED BY:** AVC – UPEI; Innovation PEI

PROJECT LEAD: Mark Fast (UPEI); Ben Koop (UVic)

PROJECT TEAM: Roy Danzmann (U. Guelph); Crawford Revie, Larry Hammell (UPEI); Brian Glebe (DFO); Ian Thompson (MUN)

COLLABORATORS: Frank Nilsen (Sea Lice Research Centre, Research Council of Norway); Simon Jones, Stewart Johnson (DFO); Simon Wadsworth (EWOS Innovation, Norway)

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Researcher Mark Fast holding an Atlantic Salmon used in one of his research projects. *Photo: Mark Fast (UPEI)*

FISH HEALTH

Continued market access for Alberta commercial aquaculture producers through the development of fish health management plans

Identification and quantification of *Kudoa thyrsites*-specific DNA in seawater

Identification and treatment of gyrodactylid infections in cultured Wolf Eels

Implementation of real time PCR for fish pathogen screening at the BC Centre for Aquatic Health Sciences

Genomic characterization of jaundice-associated mortality events in cultured Chinook Salmon

Health assessment of juvenile Fraser River Sockeye Salmon in the Strait of Georgia and adjacent waters

Refinement of an Infectious Hematopoietic Necrosis Virus dispersion model for the Discovery Islands area and an extension to west coast of Vancouver Island

Validation of dietary medication and sterilised seawater to reduce the severity of *Kudoa thyrsites* in farmed Atlantic Salmon

Field validation of dietary medication to reduce the severity of *Kudoa thyrsites* in farmed Atlantic Salmon

Epitheliocystis in salmonids

Improved management strategies for Bacterial Cold Water Disease

Viral Hemorrhagic Septicemia Virus (VHSV) and Great Lakes fish

Low pathogenic Infectious Salmon Anemia Virus (ISAV) *in vivo*: a comparative genomic study

Deoxynivalenol and disease susceptibility to Cold Water disease and immunity in Rainbow Trout

Detection and pathogenesis of Spring Viremia of Carp Virus (SVCV) in Ontario baitfish

Evaluation of membrane filtration and UV disinfection for the control of *Flavobacterium psychrophilum* in recirculation aquaculture systems

Innate immunity of teleosts; pattern-recognition receptors and acute phase response

Antigen presentation in teleost fish

Early detection of "Soft flesh" in Atlantic Salmon

DNA vaccine models against ISAV

Development of novel RNA-based treatments against ISAV

CONTINUED MARKET ACCESS FOR ALBERTA COMMERCIAL AQUACULTURE PRODUCERS THROUGH THE DEVELOPMENT OF FISH HEALTH MANAGEMENT PLANS

Alberta commercial fish culturists held discussions with their Provincial government regulators in late 2010, on the topic of compulsory requirements for Fish Health Management Plans (FHM Plan).

The goal of this project has been to cooperatively assist commercial fish culturists in Alberta to complete an accredited Fish Health Management Plan, following the developed template, as well as a document of "Required Elements" (to help explain each section of the FHM Plan) and a background document on related aspects of certification and marketing.

The objectives of the project were to:

1) Set up a new Alberta Fish Health Management Plan by modifying the existing Province of British Columbia's Fish Health Management Plan template.

2) Coordinate the development of Alberta's Fish Health Management Plan with Alberta Aquaculture Association (AAA), Alberta Agriculture and Rural Development, (AARD), Alberta Sustainable Resource Development (ASRD), and Canada Food Inspection Agency (CFIA), maintaining close liaison throughout the process.

3) Assist each fish culturist with fine-tuning of their individual plan.

Alberta's commercial fish culturists now have a completed Fish Health Management Plan for each of its members, and a Template available for new entrants. The updated template will be accessible to aquaculture producers across Canada, in particular, the Prairie Provinces, who may wish to use it for their facility operations.

MAY 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Alberta Agriculture and Rural Development

PROJECT LEAD: Mark McNaughton (Alberta Aquaculture Association)

PROJECT TEAM: Mark McNaughton (Alberta Aquaculture Association); Eric Hutchings (Lethbridge Consulting Company)

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IDENTIFICATION AND TREATMENT OF GYRODACTYLID INFECTIONS IN CULTURED WOLF EELS

Wolf Eels (*Anarrhichthys ocellatus*) are considered an appropriate new species for development in the Canadian aquaculture industry. Recent research has looked at the potential to move this culture species from experimental to commercial production. During their studies, researchers identified the *Gyrodactylus* spp. as a commonly occurring parasite that is responsible for recurring outbreaks in captive reared Wolf Eels and which impedes production. Wolf Eels are cultured in high density to prevent innate aggressive behaviour. They also have a high reproduction rate. These two factors are thought to contribute to the fast spread of the parasite amongst cultured fish. The objective of this project is to investigate *Gyrodactylus* outbreaks occurring in captive reared Wolf Eels, identify the species responsible and develop an efficacious treatment protocol.

The first phase of research will involve the identification of the species of *Gyrodactylus* responsible for the disease outbreaks. This will include the collection of information on parasite reproduction and life cycle which will be used to develop treatment protocols. The second phase will be to conduct controlled studies to investigate the effectiveness of different treatments (e.g., freshwater, hydrogen peroxide, formalin) and treatment protocols (dose, duration, frequency) in reducing and eliminating infections. Additional information will also be collected on various aspects of *Gyrodactylus* infections in Wolf Eels including the behavioural, physiological, and immunological responses of the Wolf Eels to infections and parasite site preferences (i.e., gill *vs* skin).

This research is needed to assess risk, develop treatment protocols and to provide new information that will be essential for a successful Wolf Eel aquaculture industry.

OCT. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP); Kyuquot SEAfoods Ltd.

PROJECT LEAD: Simon Jones (DFO)

PROJECT TEAM: Shannon Balfry, Denis Thoney (Vancouver Aquarium)

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IDENTIFICATION AND QUANTIFICATION OF *KUDOA THYRSITES*-SPECIFIC DNA IN SEAWATER

The parasite *Kudoa thyrsites* can cause soft-flesh syndrome that affects the flesh quality in post-harvest Atlantic Salmon farmed in British Columbia. Although fish infected with the parasite show no clinical signs of disease, muscle in the processed fillet rapidly deteriorates, resulting in economic losses to the industry. Knowledge is limited on the life cycle of *K. thyrsites* and there are no vaccines or approved treatments for the parasite; however, researchers are exploring candidate treatments. Most species of *Kudoa* have only been identified from within the specific cells or tissues of their fish hosts. All other aspects of their life cycle, including how the parasite enters and migrates within the fish and the alternate host species are unknown; however, it is hypothesized that the infective stages occur in seawater

The proposed research will develop a test for the detection of the waterborne fish-infective stage of *K. thyrsites*. The method will be validated and used to screen water samples from commercial production sites historically known to be at risk for *K. thyrsites* infection. These samples will be taken at various depths and times. This will help assess the seasons and water depths when changes occur in the abundance of the infective stage, in the marine environment.

OCT. 2012 – FEB. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP); Marine Harvest Canada; BC Centre for Aquatic Health Sciences (CAHS)

PROJECT LEAD: Simon Jones (DFO)

PROJECT TEAM: Wyth Marshall, Ahmed Siah (BC CAHS); Diane Morrison (Marine Harvest Canada)

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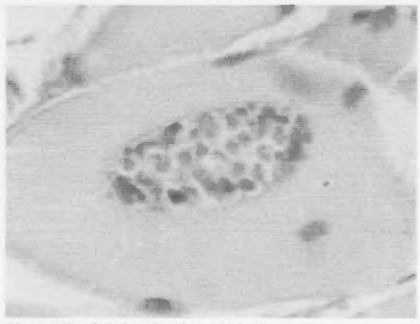

Plasmodia of *Kudoa thyrsites* within the muscle. Photo: BC CAHS

LOW PATHOGENIC INFECTIOUS SALMON ANEMIA VIRUS (ISAV) *IN VIVO*: A COMPARATIVE GENOMIC STUDY

Drawing blood for ISAV analysis. *Photo: Nellie Gagné (DFO)*

Since the initial identification of ISAV in Norway in 1984, and in the Bay of Fundy in 1996, viral evolution and selective pressure, combined with improved detection have revealed an interesting and challenging Infectious Salmon Anaemia virus (ISAV) portrait: the presence of essentially avirulent strains such as the HPR0 variant, as well as highly virulent strains, such as HPR4 variants. Additionally, there are many other strains identified which have varying degrees of virulence. The ISAV remains a looming threat to the salmon aquaculture industry, and ISAV continues to evolve. This study will contain an in-depth assessment of the etiology of ISAV to gain further understanding of the variable virulence and infection dynamics observed *in vivo* in salmon.

MAR. 2011 – MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

PROJECT LEAD: Nellie Gagné (DFO)

PROJECT TEAM: Mark Laflamme, Francis Leblanc, Brian Glebe, Mélanie Roy, Steve Leadbeater (DFO); Keng Pee Ang (Kelly Cove Salmon Ltd.)

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IMPLEMENTATION OF REAL TIME PCR FOR FISH PATHOGEN SCREENING AT THE BC CENTRE FOR AQUATIC HEALTH SCIENCES

This project aims at implementing a qPCR screening test for fish health diagnostics at the BC Centre for Aquatic Health Sciences (BC CAHS). Although cell culture remains the "Gold Standard" screening technique for fish health, real-time qPCR allows a high-throughput, sensitive and rapid turn-around time screening.

Due to its close location to the fish farms, strong collaboration with fish farm industry and its involvement in research projects on wild fish surveillance programs, BC CAHS in collaboration with Mainstream Canada has implemented a qPCR screening assay for fish health surveillance. BC CAHS is currently performing a qPCR screening for IHNV, VHSV, ISAV and *Renibacterium salmoninarum*. In addition, experiments have been performed to evaluate the Elongation Factor alpha 1 mRNA as a suitable indicator of Atlantic Salmon tissue quality control.

Further assays are currently under development in order to screen for *Aeromonas salmonicida* and *Yersinia ruckeri*. Furthermore, BC CAHS is starting the process of ISO 17025 accreditation for fish health diagnostics.

SEPT. 2011 – SEPT. 2013

FUNDED BY: Mainstream Canada; Western Diversification (ISO 17025 Accreditation)

PROJECT LEAD: Ahmed Siah (BC CAHS)

PROJECT TEAM: Henrik Duesund, Kathleen Frisch, Peter McKenzie (Mainstream Canada); Kathryn Temple, Sonja Saksida (BC CAHS)

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HEALTH ASSESSMENT OF JUVENILE FRASER RIVER SOCKEYE SALMON IN THE STRAIT OF GEORGIA AND ADJACENT WATERS

It is generally accepted that pathogen transfers occur between wild and farmed salmonids, and that these transfers occur in both directions. What is not understood, however, is the magnitude of these transfers and the risk that they pose to both wild and farmed salmonids. For the last 3 years (2010 – 2012) we have monitored the health of juvenile Sockeye Salmon during their migration down the Fraser River and through the Strait of Georgia and Johnstone Strait. We have used traditional diagnostic methods and validated molecular diagnostic techniques to screen sockeye for a variety of pests, including sea lice (*Lepeophtheirus salmonis* and *Caligus clemensi*), and viruses and have used histology to look for signs of disease. Sea lice are also being counted on other species of juvenile salmon and non-salmonids. In addition to improving our understanding of pathogens and diseases of Sockeye Salmon, our surveys are providing important information on the distribution, routes of migration and stock makeup of juvenile salmon in the Strait of Georgia and Johnstone Strait. Taken together all of these data along with data from the salmon farming industry will help in the assessment of risks associated with the transfer of pathogens between wild and farmed salmon.

MAY 2010 – JULY 2012

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR) **CO-FUNDED BY:** BC Pacific Salmon Forum; Pacific Salmon Commission Southern Fund (Apr. – July 2012)

PROJECT LEAD: Stewart Johnson (DFO)

PROJECT TEAM: Kyle Garver, Simon Jones, Chrys Neville, Marc Trudel (DFO)

CONTACT: Stewart.Johnson@dfo-mpo.gc.ca

Juvenile Sockeye Salmon. *Photo: Ted Sweeten (DFO)*

REFINEMENT OF AN INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS DISPERSION MODEL FOR THE DISCOVERY ISLANDS AREA AND AN EXTENSION TO WEST COAST OF VANCOUVER ISLAND

Since the introduction of Atlantic Salmon to the BC coast in the mid 1980's there have been two serious outbreaks of Infectious Hematopoietic Necrosis virus (IHNV) in farmed Atlantic Salmon: 1992 – 1996 and 2001 – 2003. In the latter outbreak, thirty-six farm sites representing both east and west coast regions of Vancouver Island were diagnosed with IHNV. The estimated economic loss resulting from both epizootics was $40 million in inventory representing $200 million in lost sales. A central question regarding outbreaks in farmed Atlantic Salmon is the role of natural waterborne transmission in the spread of virus between farms. Studies investigating spatial and temporal patterns of the IHNV outbreaks suggest that farming practices themselves contributed significantly to the spread of disease both within and between areas; however, the extent to which waterborne transmission contributes to virus dispersal during an outbreak is unclear. As research conducted under ACRDP # P-09-03-006 provided a baseline for the establishment of the first viral dispersion model, this study seeks to further these studies as described herein to refine the biological measurements of the established viral dispersion model.

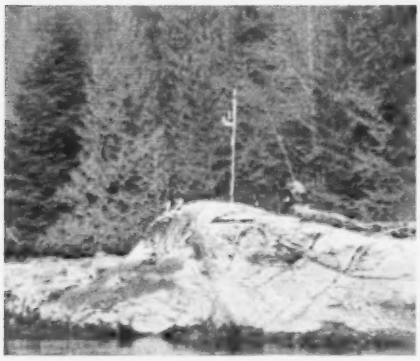
JUNE 2011 – MAR. 2013

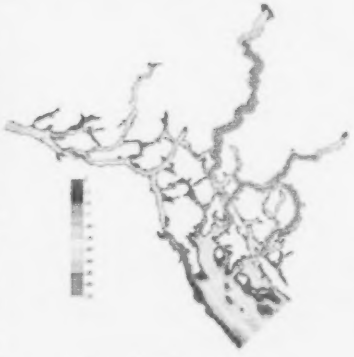
FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Grieg Seafoods BC Ltd., Mainstream Canada, Marine Harvest Canada Inc.

PROJECT LEAD: Kyle Garver (DFO)

PROJECT TEAM: Mike Foreman, Dario Stucchi, Ming Guo, Darren Tuele, Peter Chandler (DFO)

CONTACT: Kyle.Garver@dfo-mpo.gc.ca





LEFT: Weather monitoring station. RIGHT: Map of ocean currents around Discovery Islands, BC.
All Photos: Mike Foreman (DFO)

VALIDATION OF DIETARY MEDICATION AND STERILISED SEAWATER TO REDUCE THE SEVERITY OF *KUDOA THYRSITES* IN FARMED ATLANTIC SALMON

Farmed Atlantic Salmon are at risk of infection with *Kudoa thyrsites* throughout British Columbia, leading to an elevated risk of reduced fillet quality. The cost to the BC farmed Atlantic Salmon industry was over $15 million in 2010, adding to the difficulty for the BC industry to remain competitive in the global salmon market. Early screening of farmed stock is now often used for *Kudoa* detection. Neither vaccines nor medicines are currently available for the prevention or treatment of the infection. An earlier ACRDP project demonstrated the efficacy of dietary Nicarbazin, a compound used to prevent coccidiosis in poultry, against *K. thyrsites* in Atlantic Salmon. The present study will use laboratory-reared Atlantic Salmon to compare the efficacy of Nicarbazin and ultraviolet irradiation of seawater against *K. thyrsites*, and to obtain data relating to the longevity of Nicarbazin in Atlantic Salmon tissues following cessation of treatment.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Marine Harvest Canada; Mainstream Canada Ltd.; Grieg Seafood BC Ltd.

PROJECT LEAD: Simon Jones (DFO)

COLLABORATORS: Sharon DeDominicis (Marine Harvest Canada); Barry Milligan (Mainstream Canada Ltd.); Peter McKenzie (Grieg Seafood BC Ltd.)

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GENOMIC CHARACTERIZATION OF JAUNDICE-ASSOCIATED MORTALITY EVENTS IN CULTURED CHINOOK SALMON

This project was undertaken to determine whether a jaundice syndrome associated with low-level mortality in Chinook Salmon farmed in Tofino Inlet was more likely caused by a viral infection or an environmental toxin. Our project combined genomics, histopathology, epidemiology, and standard veterinary diagnostic techniques to determine which of these etiologies was more likely involved. Prevalence of jaundice syndrome was consistently greater at farm A than B over multiple years. The most significant lesions included tissue necrosis and fibrin deposition, primarily in kidney and liver. Genomic signatures comprised of thousands of differentially regulated genes occurred in both kidney and liver, with strong effects on immune response, proteolysis, metabolism, and cell cycle. The types of immune processes elicited were highly consistent with a viral etiology (response to virus, response to exogenous dsRNA, Stat signaling, type-I interferon response, viral replication); conversely, there was no signal that could be construed as toxicant-response. Based on a PCR survey of infectious agents, fish with jaundice syndrome commonly had greater loads of piscine reovirus than did healthy fish. This virus is purported to cause heart and skeletal muscle inflammation (HSMI) in Atlantic Salmon in Europe, but the lesions associated with HSMI are very different from lesions in Chinook Salmon with jaundice syndrome. Tissue tropism is not uncommon with reovirus infections, so it is possible that this virus could affect different tissues in different species. As a whole, this research supports a viral etiology, however, more research will be required to determine if the piscine reovirus is causative of, associated with, or merely a bystander to the jaundice syndrome.

APR. 2011 – APR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Creative Salmon

PROJECT LEAD: Kristi Miller (DFO)

PROJECT TEAM: Karia Kaukinen, Brad Davis (DFO); Sonja Saksida (CAHS)

COLLABORATORS: Gary Marty (BC Ministry of Agriculture)

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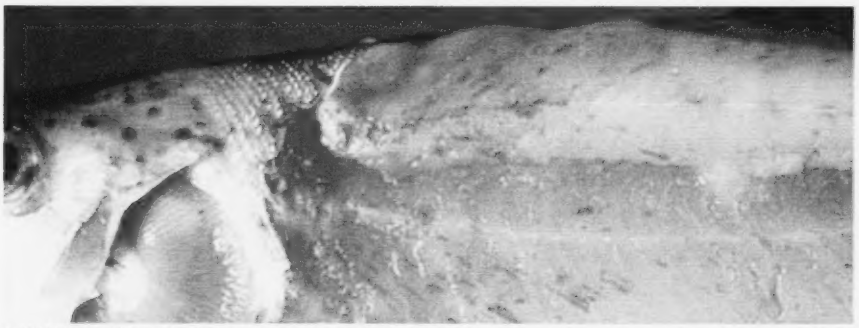
VIRAL HEMORRHAGIC SEPTICEMIA VIRUS (VHSV) AND GREAT LAKES FISH



VHSV in trout. *Photo: T. Hostein*

The purpose of the study was to provide data to predict the effect of Viral Hemorrhagic Septicemia Virus (VHSV) genotype IVb on Walleye and other fish in the Great Lakes. The first objective was to predict morbidity/mortality in naive Walleye using a biologically relevant waterborne infection and re-infection model at temperatures permissible for VHSV replication (~10-12°C). The reference strain of Walleye was not very susceptible to experimental infection via waterborne exposure (1×10^7 virions; <5% mortality) and was only moderately impacted by a large dose of virus given intraperitoneally (i.p.) (1×10^7 virions; 30-40% mortality). Walleye were more resistant than Fathead Minnows but more susceptible than Rainbow Trout using similar experimental conditions. In addition, Walleye previously waterborne-exposed to VHSV were almost completely resistant to re-infection via i.p.-injection five months later. The second objective was to determine the relative susceptibility of four genetically distinct Great Lakes Walleye strains, of which one was found to be significantly less susceptible to experimental i.p.-infection. To date, therefore, it appears likely that there is a low impact of infection with VHSV on stocked Walleye, and that strain selection would further reduce any impact. A third objective was to create new tools for the culture of VHSV and numerous Walleye cell lines have been created. In addition, the behaviour of VHSV IVa and IVb has been compared in Rainbow Trout gill epithelial and splenic macrophage cell lines. Research in Rainbow Trout and in wild fish species including Freshwater Drum and Fathead Minnow demonstrated that the virus (viral antigen and RNA) was present in eggs and sperm. Ongoing research is examining innate immune mechanisms in gill epithelium and the role of virus neutralizing antibody in protection of Walleye.

OCT. 2008 - ONGOING

FUNDED BY: Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA); NSERC Strategic; NSERC Discovery; Great Lakes Fisheries Commission; FRST New Zealand Postdoctoral Fellowship; Ontario Veterinary College Fellowship

PROJECT LEAD: John S. Lumsden (U. Guelph)

PROJECT TEAM: Lowia Al Hussinee, Alex Reid, Jessica Grice, Lincoln Tubbs, Paul Huber, (U. Guelph); Brian Dixon, John Pham, Nguyen Vo, Niels Bols (U. Waterloo)

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DEVELOPMENT OF NOVEL RNA-BASED TREATMENTS AGAINST ISAV

The purpose of the project is to develop a novel RNA interference-based vaccine against ISAV. RNA interference (RNAi) has been successfully used to combat viral infections in many vertebrate and invertebrate species, and offers the distinct advantage of being used both as a prophylactic vaccine, and as a treatment to combat the virus at the first signs of infection. We have identified genetic sequences that are common to all strains of ISAV, and we have designed, cloned and evaluated the efficacy of a number of RNAi-based gene inhibitors using model cell lines. Our results are encouraging and suggest that RNAi-based therapies could be developed against ISAV. We have noticed, however, that fish cells kept in culture over long periods of time become non-permissive to ISAV; this has caused problems in our analyses. As such, further testing will need to be done to best determine how RNAi therapies could be applied to live fish. If successful, this would represent the first and only treatment against ISAV infection.

NOV. 2009 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

PROJECT LEAD: Mark Laflamme (DFO)

PROJECT TEAM: Nellie Gagné (DFO)

COLLABORATORS: Keng Pee Ang (Kelly Cove Salmon Ltd.); Gilles Robichaud (U. Moncton)

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DEOXYNIVALENOL AND DISEASE SUSCEPTIBILITY TO COLD WATER DISEASE AND IMMUNITY IN RAINBOW TROUT

The increasing demand for fish protein has led to aquaculture being the fastest growing food producing sector in the world. This evolution has led to numerous modifications in production to sustain the demand. The replacement of fishmeal with more economical plant-based by-products in aqua feeds has led to an increased risk of exposure to mycotoxins in aquatic species. Deoxynivalenol (DON), a *Fusarium* mycotoxin, is of concern as it is the most commonly occurring mycotoxin worldwide. However, the mechanisms of action of DON and its potential role in fish health are largely unknown. Therefore, the objective of the current research was to determine if DON had any impact on the susceptibility of Rainbow Trout to Bacterial Cold Water Disease and immunity, including immunoglobulin production and macrophage function. Rainbow Trout were fed a nutritionally complete diet naturally contaminated with two concentrations of DON (4 or 6 ppm). After four weeks of feedborne exposure to DON, Rainbow Trout were experimentally infected via intraperitoneal injection with a virulent isolate of *Flavobacterium psychrophilum*. A significant reduction ($p<0.05$) in mortalities in DON-fed groups was observed in comparison to control and pair-fed groups at 21 days post infection. These findings warrant further investigation of the effects of DON on the bacterium and on Rainbow Trout immunity.

MAY 2010 – ONGOING

FUNDED BY: NSERC Discovery Grant

PROJECT TEAM: Ian Ryerse, Jamie Hooft, Dominic Bureau, Maureen Jarau, John S. Lumsden (U. Guelph)

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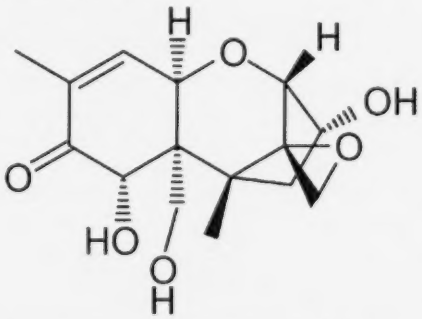
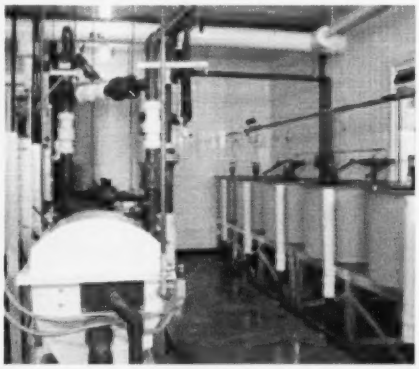


Deoxynivalenol (DON) molecular structure. *Photo: Public domain (Wikimedia Commons)*

EVALUATION OF MEMBRANE FILTRATION AND UV DISINFECTION FOR THE CONTROL OF *FLAVOBACTERIUM PSYCHROPHILUM* IN RECIRCULATION AQUACULTURE SYSTEMS



LEFT: Membrane filter. TOP RIGHT: Recirculation system at the Alma Aquaculture Research Station. BOTTOM RIGHT: Checking water flow rates. *All Photos: David Huyben and David Bevan (U. Guelph)*

Recirculation aquaculture systems (RAS) utilize disinfection technologies to remove pathogens from wastewater and improve fish health. Ultraviolet (UV) irradiation is a disinfection treatment commonly used in RAS. However, *Flavobacterium psychrophilum*, the causative agent of Bacterial Cold Water Disease (BCWD), is tolerant of recommended UV doses used in aquaculture systems. Membrane filtration (MF) has been used as a disinfection technology in many industries, but has not been thoroughly tested as a disinfection treatment in RAS. The objective of this study was to evaluate MF as a disinfection treatment in RAS and its ability to remove *F. psychrophilum*. Total bacterial removal efficiencies were assessed between MF and UV treatments over 30 days in a RAS that reared Nile Tilapia (*Oreochromis niloticus*). MF and UV had equivalent bacterial removal efficiencies and achieved 98.5% and 99.6% removal, respectively. MF also exhibited an additional benefit of removing 95.4% of total suspended solids and experienced low rates of membrane fouling. Under laboratory conditions, we challenged MF with concentrated doses of *F. psychrophilum* and achieved 5.7-log reductions of the pathogen. Therefore, MF represents an effective alternative to UV disinfection and can be used to remove *F. psychrophilum* from RAS, potentially reducing outbreaks of BCWD.

SEPT. 2010 – DEC. 2012

FUNDED BY: Environment Canada; Ontario Ministry of Food, Agriculture and Rural Affairs

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INNATE IMMUNITY OF TELEOSTS; PATTERN-RECOGNITION RECEPTORS AND ACUTE PHASE RESPONSE

Two plasma lectins, intelectin and ladderlectin, were isolated by their ability to bind to a wide range of infectious agents (PRRs) that cause disease in Rainbow Trout. Ladderlectin was found to have two isoforms and the genomic sequence encompassed six exons and five introns, with exon 2 encoding 14 amino acids that were exclusive to one isoform. Two-dimensional PAGE and western blots demonstrated multiple electrophoretic forms of both lectins. Enzyme immunoassays showed that there was significant group and individual variation in plasma lectin concentrations. Neither lectin was an acute phase reactant nor were the concentrations substantially altered during bacterial infection, however, both lectins were localized by immunohistochemistry in intimate association with microbes *in vivo*. Both lectins were widely distributed on mucosal surfaces and both were also identified on the cell surface of leukocytes and on trout cell lines. Ladderlectin, but not intelectin, also bound to VHSV, the first demonstration to our knowledge of a virus-binding PRR in fish.

Acute phase proteins were also examined in Rainbow Trout and Walleye using 1 or 2D-PAGE and mass spectrometry. Partial amino acid sequences were identified and 3' RACE was used to isolate cDNA sequences specific to these unknown proteins. A 9.5 kD Rainbow Trout acute phase protein, that underwent a 75-fold upregulation, was found to contain a conserved apolipoprotein A-I domain. A Walleye plasma protein that bound *Flavobacterium columnare* had 66% similarity to apolipoprotein A-I from Striped Bass (*Morone saxatilis*). There is therefore evidence indicating that proteins in the apolipoprotein family are involved in the acute phase response and or are PRRs of both fish. These proteins are known to contain lipid-binding domains and may act as PRRs to bind lipid components of fish pathogens during the innate immune response.

MAR. 2004 – ONGOING

FUNDED BY: NSERC Discovery and Strategic grants; Chemaphore Inc.; NSERC Fellowship; Ontario Veterinary College Fellowship

PROJECT LEAD: John S. Lumsden (U. Guelph)

PROJECT TEAM: Spencer Russell, Karrie Young, Andrew Peterson, Alex Reid, Lowia Al-Hussinee, Adrian Di Natale (U. Guelph); John Pham, Niels Bols, Brian Dixon (U. Waterloo)

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EPITHELIOCYSTIS IN SALMONIDS

Intracellular gram-negative bacteria associated with epitheliocystis, including several Chlamydia-like organisms, have been found in many fish species. In Ontario, this condition affects Arctic Charr and Lake Trout, and it has also emerged in farmed Rainbow Trout in the last two years. Diagnosis is a challenge as the organisms cannot be cultured and bacterial inclusions are present before clinical signs appear but largely disappear by the time fish are submitted for examination by light microscopy. The histological lesions are fairly consistent, however, and include prominent single-cell necrosis of leukocytes and epithelial cells, in addition to thickening and blunting of lamellae. Identification of the agent from fresh and formalin-fixed gill tissue of affected salmonid species is a priority of this project. Primers described for detection of the 16S rRNA gene of Chlamydiales and 16S rRNA universal bacterial primers have generated a 300 bp and 1500 bp products, respectively. Two sequences have been consistently identified; one with 88% similarity to an uncultured *Neochlamydia* sp. isolated from a cat with ocular disease and another with 90% similarity to *Candidatus brachiomona cysticola*, which was also recently identified from Atlantic Salmon with epitheliocystis in Norway. Localization of organisms in affected gills using *in situ* hybridization and laser microdissection are in progress. Transmission trials and attempts to culture the organism using a Rainbow Trout gill epithelial cell line are also underway.

MAR. 2011 – MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

PROJECT LEAD: Nellie Gagné (DFO)

PROJECT TEAM: Mark Laflamme, Francis Leblanc, Brian Glebe, Mélanie Roy, Steve Leadbeater (DFO); Keng Pee Ang (Kelly Cove Salmon Ltd.)

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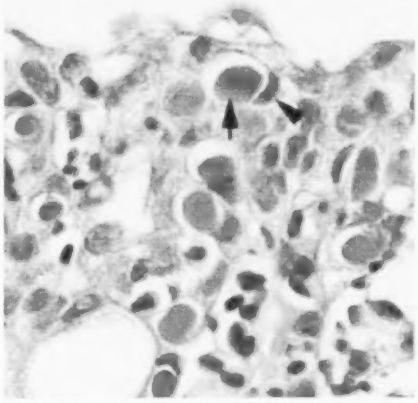

Epitheliocystis in gills of seawater farmed Atlantic Salmon. *Photo: Toenshoff et al. – PLoS ONE (2012)*

DETECTION AND PATHOGENESIS OF SPRING VIREMIA OF CARP VIRUS (SVCV) IN ONTARIO BAITFISH

Spring viremia of carp is a World Organization of Animal Health (OIE) reportable viral disease. SVCV has been recently isolated from carp in Hamilton Harbour, Ontario, Canada. The first aim of the study is to assess the ability of SVCV to infect Ontario baitfish, including Emerald Shiner, Fathead Minnow, and White Sucker. These fish are commonly moved between watersheds and may spread SVCV to new locations. Experimental infection trials have been performed using the Canadian isolate of SVCV (HHOcarp06) using intraperitoneal injection of fish of interest. SVCV caused morbidity and mortality in Flathead Minnow, Emerald Shiner, Koi, and White Sucker, but not in Rainbow Trout. The pathogenicity of disease is being assessed using histopathology and immunohistochemistry. The second aim is to discover if SVCV is more widespread in Ontario than presently realized. A retrospective study is underway using RT-qPCR to detect viral RNA from numerous fish species collected by the Ontario Ministry of Natural Resources (OMNR) from 2008 to 2012. The sensitivity of the RT-qPCR was assessed in tissues spiked with virus dilutions. In conclusion, at least three Ontario baitfish species are at some risk from SVCV, however, further analysis of tissues and results is required.

MAY 2010 – ONGOING

FUNDED BY: OMNR; Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA); Egyptian Government Graduate Scholarship; FRST New Zealand Postdoctoral Fellowship; NSERC USRA

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IMPROVED MANAGEMENT STRATEGIES FOR BACTERIAL COLD WATER DISEASES

Bacterial Cold Water Disease (BCWD) caused by *Flavobacterium psychrophilum* is the most important infectious disease for Ontario Rainbow Trout aquaculture. Several aspects of BCWD have been studied in this research but most are focused on improved management options for farmers. Isolate phenotypic and genotypic variability and antimicrobial susceptibility profiles were compared between Ontario and BC isolates and Ontario isolates were more diverse, however, an association was not found to correlate a bacterial characteristic to clinical presentation. The effect of erythromycin, available only as an emergency drug, was compared with that of florfenicol in a farm trial and both appeared to be equally effective. Autogenous vaccines were trialed on-farm and in the laboratory but they have not been effective. Cold-induced proteins and genes were identified that may be virulence factors and several of the gene products have been cloned and expressed as recombinant proteins for further research. A range of Ontario isolates was used to demonstrate a wide variability in virulence in experimental trials. Morbidity and mortality are being correlated with splenic bacterial colony forming units and quantitative PCR to provide an endpoint before mortality and shorten the length of trials. The breeding program at Lyndon Hatcheries is presently supplying family fish that are being tested for susceptibility to experimental infection with a virulent Ontario isolate. These families are also being examined for MH and immune genes.

MAY 2007 – ONGOING

FUNDED BY: Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA); NSERC Strategic and CRD (with the Freshwater Fisheries Society of British Columbia and Microtek Inc.); DFO – Aquaculture Collaborative Research and Development Program (ACRDP) (with Lyndon Hatcheries Ltd.); Ontario Veterinary College Fellowship

PROJECT TEAM: Shohreh Hesami, Arman Yazdanpanah, Maureen Jarau, Lowia Al-Hussinee, Paul Huber, Glen Soltes, Jan MacInnes, John S. Lumsden (U. Guelph); Samantha Hodgins, Calvin Kellendonk, Brian Dixon (U. Waterloo); Sean Pressey, Clarke Rieck (Lyndon Hatcheries)

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ANTIGEN PRESENTATION IN TELEOST FISH

Antigen processing is the pathway in which proteins from pathogens are targeted by the host immune response. Despite a fairly detailed knowledge of the genes and proteins that are involved in this process in mammals, the proteins involved in this pathway and their specific interactions are unknown. This project has cloned the genes for those genes involved in this pathway which have not been isolated to date, characterized them and has produced antisera for them. Immunohistochemistry and co-immunoprecipitation are employed to investigate the protein interactions within this pathway.

To date in this project calreticulin has been cloned and characterized. It is located in the endoplasmic reticulum (ER) and responds to immune stimulation, but not to ER stress. ERP57 has also been cloned and characterized. This gene is duplicated in salmonids, with one version having what may be a functional ER retention signal, while the other has a nuclear localization signal. This suggests a division of the roles undertaken by mammalian ERP57. Antibodies have also been generated to MHC class I, beta-2 microglobulin, TAP, and Calnexin. The regulation of these proteins during immunostimulation is being investigated, but initial co-immunoprecipitation studies have shown that tapasin and MHC class I interact within the ER of the RTS11 Rainbow Trout macrophage cell line.

Understanding the process by which pathogenic proteins are identified by fish immune systems will assist in designing vaccines that can elicit strong, effective immune responses in fish. This will hopefully prevent losses to disease, enhancing profitability of aquaculture operations.

MAR. 2008 – ONGOING

FUNDED BY: NSERC Discovery

PROJECT LEAD: Brian Dixon (U. Waterloo)

PROJECT TEAM: Lital Sever, Niels Bols, Nguyen Vo, Brian Dixon (U. Waterloo)

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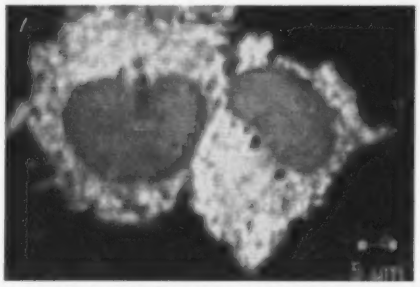

The localization of Rainbow Trout ERp57 in the endoplasmatic reticulum of the RTS11 macrophage-like cells line. *Image: L. Sever, N. Bols, B. Dixon (U. Waterloo)*

EARLY DETECTION OF "SOFT FLESH" IN ATLANTIC SALMON

***Kudoa thyrsites* is a marine** myxosporean parasite, endemic to the West Coast of Canada, which infects fish and causes post mortem myoliquefaction. Atlantic Salmon are susceptible to infections and this has resulted in significant economic losses to the aquaculture industry. There are several diagnostic tests that can be used to detect infections in fish including molecular tests; however, most of these tests require lethal sampling and results are not available for several days. We proposed to evaluate the sensitivity and specificity of ultrasound for detecting fish infected with *K. thyrsites*. This technology has been used to detect changes in muscle structure in other animals and provides a rapid assessment of soft tissues. We hypothesize that using computer image analysis of ultrasound images we will be able to identify fish that will develop post mortem myoliquefaction before they develop the condition. If successful this technology has the potential to be used on a large scale at processing plants to identify fish that are not well suited for the "fresh" market.

Kudoa thyrsites infection in salmon. *Photo: Kristi Miller (DFO)*

SEPT. 2012 – SEPT. 2013

FUNDED BY: UPEI CERC grant

PROJECT LEAD: Sophie St-Hilaire (UPEI)

PROJECT TEAM: LeeAnn Pack, Tim Burnley, Sohrab Ameli (UPEI); Sonja Saksida (CAHS)

COLLABORATORS: Centre for Aquatic Health Sciences (CAHS); Marine Harvest

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DNA VACCINE MODELS AGAINST ISA

The goal of this project is to explore the feasibility of new DNA model vaccines against ISAV. It is a novel approach using plasmid constructs expressing ISAV protein subunits combined to an HSP binding sequence, with a suitable linker and signal sequence. Several antigenic ISA proteins and peptides will be selected, from full length protein to single epitopes. The various plasmid constructs will be tested *in vivo*, and RPS values (relative protection survival) will be determined by comparison to vector alone. To achieve this goal we will: 1) produce recombinant vectors for the expression of specific ISAV genes; 2) prepare sufficient quantities of recombinant vectors for a vaccine trial; 3) do a vaccine trial using different vaccine formulation; and 4) detect DNA vaccine, *in situ* transcription and measure genomic markers of immune response after vaccination.

JULY 2009 – DEC. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Atlantic Canada Fish Farmers Association (ACFFA)

PROJECT LEAD: Nellie Gagné (DFO)

PROJECT TEAM: Mark Laflamme, Nathalie Simard (DFO); Lisa Phillips, Kira Salonius (Novartis Animal Health Canada Inc.)

COLLABORATORS: Novartis Animal Health Canada Inc.

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ENVIRONMENTAL INTERACTIONS

Refinement of DEPOMOD validations for freshwater finfish sites

Establishing zones for managing risks related to pathogens and/or pollutants originating on finfish aquaculture facilities in the Broughton Archipelago and Discovery Islands

Impacts of Pacific Herring on the health of farmed Atlantic Salmon in BC

Effects of freshwater aquaculture on freshwater benthic communities

Distribution and concentration patterns of SLICE® in sediments at high, medium, and low energy aquaculture sites on the west coast

Support for the development of a draft sediment monitoring program for freshwater cage aquaculture

To validate the robustness of ecosystem carrying capacity models

Analysis of relationships between bivalve aquaculture and eelgrass coverage at a bay-wide scale

Developing a carrying capacity framework for Baynes Sound, BC

Environmental information system for aquaculture, Phase 2

Assessing trace-element indicators of benthic organic enrichment associated with aquaculture activities

Assessing the value of bivalve meat as an indicator of ecosystem health

Influence of Eastern Oyster aquaculture overwintering on eelgrass

Evaluating *Beggiatoa* and OPC as indicators of benthic habitat conditions on hard ocean substrates using visual data collected seasonally at new finfish aquaculture sites and near the end of production at established sites

Comparing the impact of bottom and suspended oyster culture on bay-scale food resources

Exploration of methodologies for environmental effects monitoring of finfish aquaculture sites in sandy bottom environments with natural disturbances: Shelburne, NS

Assessing and mitigating risk from a diversifying aquaculture industry: the potential for interaction between escapee and wild Atlantic Cod

Determination of the potential spatial overlap and interaction between commercial fisheries (American Lobster, Snow Crab) and finfish aquaculture activities in Connaigre Bay, Newfoundland

Validation of DEPOMOD with a comparison of visual techniques for observing spatial and temporal variability in the benthos at active and fallowed finfish sites in Newfoundland

Quantifying benthic transport of aquaculture waste material for inclusion in predictive models

Evaluation of the FVCOM modelling system to map the far-field dispersal of aquaculture waste

REFINEMENT OF DEPOMOD VALIDATIONS FOR FRESHWATER FINFISH SITES

LEFT: Collecting a water sample. *Photo: Cindi Wlasichuk* MIDDLE: Sediment coring. *Photo: Cheryl Podemski (DFO)* RIGHT: ROV sediment traps. *Photo: Jamie Raper (DFO)*

The project objective is further validation of DEPOMOD as an environmental management tool for the trout cage culture industry in Ontario, and builds on work funded through the Aquaculture Collaborative Research and Development Program (ACRDP). DEPOMOD is a dispersion model designed for marine aquaculture that is increasingly used in several countries, but has never been validated in freshwater. Fisheries and Oceans Canada (DFO) Fisheries Protection and the inland aquaculture regulators need a defensible dispersion modelling tool to assist with the review of new site license applications and with decisions regarding applications for changes to feed quotas. Additionally, predictions of the spatial extent of the deposition footprint may be used within the development of a new aquaculture sediment monitoring program in Ontario. The purpose of this project is to continue validation of DEPOMOD, and to focus on means of improving data collection and model parameterization to improve model agreement. The primary focus will be on a validation with a comprehensive sample collection at a site that is fixed to shore thereby providing minimal uncertainty in cage location, but the effect of cage movement and of temporal variability in wind-driven turbulence will be explored using other data sets available. Comparison of model predictions with surface sediment chemistry and benthic invertebrate community structure may provide a stronger agreement with model outputs than short term sediment traps because these parameters will integrate the effects of waste deposition and cage movement over time.

JUNE 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR) **CO-FUNDED BY:** Ontario Ministry of Foods and Rural Affairs; Northern Ontario Aquaculture Association

PROJECT LEAD: Cheryl Podemski (DFO)

PROJECT TEAM: Padala Chittibabu, Paula Azevedo, Doug Geiling, Jian Zhang, Cyndi Wlasichuk, Jamie Raper (DFO)

COLLABORATORS: Coldwater Fisheries; Northern Ontario Aquaculture Association

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ESTABLISHING ZONES FOR MANAGING RISKS RELATED TO PATHOGENS AND/OR POLLUTANTS ORIGINATING ON FINFISH AQUACULTURE FACILITIES IN THE BROUGHTON ARCHIPELAGO AND DISCOVERY ISLANDS

This project will modify circulation and particle tracking models already developed through previous PARR and Aquaculture Collaborative Research and Development Program (ACRDP) projects, and in consultation with DFO Aquaculture Management and Habitat Divisions and members of the Broughton Archipelago Management Plan (BAMP) to support the establishment of zones for managing risks related to pathogens and/or pollutants originating on finfish aquaculture facilities (farms and processing plants) in the Broughton Archipelago and Discovery Islands. Particle release studies, for as wide a set of oceanographic conditions as the lateral boundary and atmospheric forcing fields permit, will be carried out to compute probability fields that reflect the zones of influence for all or a representative subset of farms in these regions. These "water movement" zones will be combined with information on wild fish migration patterns and survival (as determined by a comprehensive literature review) to produce management zones for DFO Fisheries Protection and Aquaculture Management.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR) **CO-FUNDED BY:** BAMP

PROJECT LEAD: Mike Foreman (DFO)

PROJECT TEAM: Diane Masson, Peter Chandler, Kyle Garver, Dario Stucchi, Darren Tuele, Michael Ikonomou, Stewart Johnson, Marc Trudel (DFO)

COLLABORATORS: Marine Harvest Canada; Broughton Archipelago Monitoring Program (BAMP)

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IMPACTS OF PACIFIC HERRING ON THE HEALTH OF FARMED ATLANTIC SALMON IN BC

Aquaculture within sea-cages leads to possible disease risks from the marine environment due to the generality that fish sharing water are likely to share diseases. Unless rigorous biosecurity practices are implemented, equivalent to quarantine conditions, there is almost certain to be some disease interactions between farmed and wild fish species. A particular species of interest is the Pacific Herring, *Clupea pallasi*, which is known to inhabit Atlantic Salmon sea-cages. Pacific Herring are known to carry bacteria such as *Aeromonas salmonicida* and are possible vectors for *Renibacterium salmoninarum*, the causative agent of Bacterial Kidney Disease. With the close interaction between herring and farmed Atlantic Salmon it is important to understand diseases of herring and pathogens that may be transmitted to salmonids. The goals of this research are to identify herring pathogens that pose risks to Atlantic Salmon, develop a better understanding of Viral Hemorrhagic Septicemia (VHS) virus isolates from herring and Atlantic Salmon, and identify if VHS can cause disease in Atlantic Salmon.

OCT. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Herring Conservation and Research Society; Marine Harvest Canada Inc.; Mainstream Canada; Grieg Seafoods BC Ltd.

PROJECT LEAD: Kyle Garver (DFO)

PROJECT TEAM: Jan Lovy, Paulina Piesik (DFO)

COLLABORATOR: Paul Hershberger

CONTACT: Kyle.Garver@dfo-mpo.gc.ca

Paulina Piesik working in the lab. *Photo: Jan Lovy (DFO)*

DISTRIBUTION AND CONCENTRATION PATTERNS OF SLICE® IN SEDIMENTS AT HIGH, MEDIUM, AND LOW ENERGY AQUACULTURE SITES ON THE WEST COAST

The aim of this research project is part of the broader-scope DFO objective of assessing the potential impact of commercial salmon fish farming on the health of the surrounding marine ecosystem. Specifically, this study looks at the effect of finfish farm sea lice treatments on non-target organisms. Current fish farming practices include the use of in-feed chemical treatments for controlling sea lice such as SLICE®, an in-feed treatment that includes emamectin benzoate (EB) as its active ingredient.

This study builds on previous research done in the Broughton Archipelago to assess the effects of SLICE® on Spot Prawns. Sediment samples have been collected close to aquaculture sites to determine the distribution and concentration patterns of SLICE® in the sediments (surface and sediment cores) under a wide range of oceanographic conditions: at high, medium and low energy aquaculture sites on the west coast. The biodegradation characteristics of SLICE® in marine sediments will also be examined to determine how long these chemicals may persist in the environment and at what concentrations.

The overall findings of these studies will increase our knowledge of the potential effects of SLICE® applications at marine cage finfish farm locations on the surrounding benthic environment. The measured environmental EB concentrations will be used to test, calibrate, and implement the DEPOMOD (modeling system) and other biophysical models to help predict the behaviour of EB in relevant aquatic ecosystems. These findings will be useful in forming regulations for the use of SLICE® in the aquaculture industry.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR) **CO-FUNDED BY:** BAMP

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EFFECTS OF FRESHWATER AQUACULTURE ON FRESHWATER BENTHIC COMMUNITIES

The project will look at whether the impacts to fish habitat in the high depositional area under freshwater farms, as measured by benthic community alteration, is off-set by enrichment effects observed distant to the farm. This will support the current Fisheries and Oceans Canada (DFO) Fisheries Protection Program practice of determining freshwater finfish farms to be low risk. Additionally, the project will generate knowledge of the community response of freshwater benthic invertebrates to a gradient of disturbance by organic enrichment. Specific objectives are: 1) taxonomic analysis of existing invertebrate samples collected along distance transects at commercial farms; 2) determination of individual and community biomass of individuals; 3) mapping of invertebrate abundance and biomass along a transect from farm sites to reference sites; 4) spatial extrapolation of data from transects to determine relative losses/gains in biomass due to farms; and 5) assessing the benthic invertebrate 'fitness' through biometrics along a gradient in organic waste deposit.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR) **CO-FUNDED BY:** DFO Fisheries Protection Branch

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PROJECT TEAM: Megan Otu, Jian Zhang (DFO)

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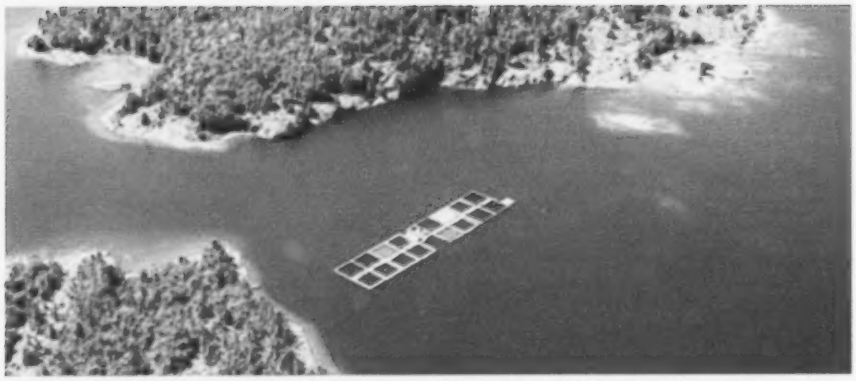
Megan Otu working at a microbalance. *Photo: C. Podemski (DFO)*

SUPPORT FOR THE DEVELOPMENT OF A DRAFT SEDIMENT MONITORING PROGRAM FOR FRESHWATER CAGE AQUACULTURE



Aerial photograph of a freshwater trout farm on Lake Huron. *Photo: Northern Ontario Aquaculture Association (NOAA)*

This project provides partial support for the development of a draft sediment monitoring program for aquaculture-affected freshwater sediments. The development of the monitoring program is a component of the Coordinated Application, Review and Decision Guidelines for Cage Aquaculture Sites in Ontario. Fisheries and Oceans Canada is providing data and technical assistance, to this Ontario Ministry of Natural Resources lead initiative, with the Ontario Ministry of Environment and Environment Canada as co-participants. Sulfide, which is often a key measure within marine monitoring programs, is not a reliable indicator of the accumulation of aquaculture waste in freshwater, and an alternative needs to be identified. The use of a geochemical indicator is preferable to biological monitoring because of reduced time and costs, but a surrogate measure must provide a reliable indicator of biological condition. Existing DFO data sets will be examined to identify potential indicators that can be directly linked to aquaculture activities, which have low variability to minimize sampling requirements, and which have a correlation with changes observed in biological communities. Data sets will be further analyzed for predictive relationships and to identify potential thresholds to inform and trigger further monitoring or management actions.

JAN. 2006 – MAR. 2012

FUNDED BY: Ontario Ministry of Natural Resources (OMNR)
CO-FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR); OMoE; DFO – Aquaculture Collaborative Research and Development Program (ACRDP); OMAFRA

PROJECT TEAM: Kristin Hynes (DFO); Lee Grapentine, Jacqui Milne (Environment Canada); Duncan Boyd, Ngan Diep (OMoE); Lisa Miller Dodd (OMNR); Gord Cole (Aquacage Fisheries); Cheryl Podemski (DFO)

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WWW.MNR.GOV.ON.CA/STDPRODCONSUME/GROUPS/LR/@MNR/@LETSFISH/DOCUMENTS/DOCUMENT/263024.PDF

ANALYSIS OF RELATIONSHIPS BETWEEN BIVALVE AQUACULTURE AND EELGRASS COVERAGE AT A BAY-WIDE SCALE

The project will examine if a potential relationship between eelgrass and bivalve aquaculture can be detected at a bay-wide survey scale and evaluate if there is a level at which bivalve aquaculture starts to negatively impact fish habitat (eelgrass). The relationship between eelgrass coverage (a proxy of eelgrass productivity) and depth distribution (a proxy of water transparency) with aquaculture density (a proxy of bivalve filtration) will be analyzed. Field surveys and mapping were conducted to quantify eelgrass and aquaculture in bays in the Gulf region with a range of ratios of aquaculture: eelgrass coverage. Land-use data will be added as co-variables and multivariate statistical analyses will be conducted to examine the shape of the relationship between aquaculture coverage (or density) and eelgrass bed coverage, and between aquaculture and eelgrass depth distribution. If asymptotes and inflection points are observed, it could indicate that ecosystem change is occurring due to aquaculture activities.

SEPT. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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TO VALIDATE THE ROBUSTNESS OF ECOSYSTEM CARRYING CAPACITY MODELS

The removal of phytoplankton by densely stocked mussels may exceed the capacity of the ecosystem to renew phytoplankton populations. In this project, the robustness of ecosystem models will be validated in Malpeque Bay (PEI), which has a large watershed area (592,000,000 m^3). Other distinctive features include an intricate river system running into Malpeque and multiple connection points between Malpeque and the Gulf of St. Lawrence. Together these features represent a challenging and therefore suitable environment to validate the ongoing development of ecosystem models for shellfish aquaculture. A second rationale for the project relates to the management of aquaculture in a proactive manner. The total area presently allocated to mussel farming in Malpeque Bay is approximately 600 ha. However, the PEI Lease Management Board is engaged in a planning exercise regarding any future releases of acreage in Malpeque Bay for mussel culture. The results from this project will help identify the optimal distribution and configuration of new leases within the bay.

JUNE 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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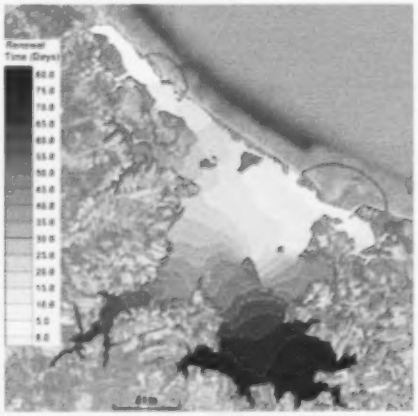

Spatial distribution of water renewal time in Malpeque Bay, PEI, forced by tides. Critical information for estimating the availability of food for cultured bivalves. *Photo: Thomas Guyondet (DFO)*

DEVELOPING A CARRYING CAPACITY FRAMEWORK FOR BAYNES SOUND, BC

The successful culture of suspension-feeding shellfish relies on the natural replenishment of phytoplankton in a culture area. This replenishment can occur via flushing, where water exchange brings in new phytoplankton, or through primary production in the area. When the population of cultured shellfish in an area is large, there is the potential that the cultured animals will deplete food particles from the water column much faster than it can be replenished. This is known as 'farm depletion' and can be an indicator that the population of cultured shellfish is exceeding the production carrying capacity of the area. Exceeding carrying capacity is a concern to both regulators and industry because of the potential environmental and ecosystem effects that might result and because insufficient food supply negatively impacts on shellfish growth.

The goal of this research project is to develop a framework to assess carrying capacity for shellfish production in Baynes Sound, BC, an area that is home to a significant shellfish culture industry and also one that has been identified by Fisheries and Oceans Canada for integrated coastal zone management. The framework will focus on establishing a particulate budget for Baynes Sound to help determine carrying capacity and also provide a real-time assessment of current benthic and pelagic conditions to aid in the development of siting criteria.

The project will also collect hydrodynamic data needed to develop a Finite Volume Circulation Model (FVCOM) to help describe the water circulation patterns in the sound as well as data to better characterize biological controls on phytoplankton concentrations in Baynes Sound. The change in abundance and size range of phytoplankton in the Sound will be used to determine whether wild and cultured shellfish are depleting their food supply faster than it can be replenished. These models, coupled with shellfish filtration, assimilation, and faecal production estimates, will be used to determine the influence of shellfish production on benthic and water column exchanges and be used to assess the carrying capacity of the Sound.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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ASSESSING TRACE-ELEMENT INDICATORS OF BENTHIC ORGANIC ENRICHMENT ASSOCIATED WITH AQUACULTURE ACTIVITIES

Aquaculture wastes, such as faeces or uneaten food, can accumulate beneath and near farm sites. In the near-field, this accumulation is predictable using depositional modelling tools such as DEPOMOD, and the organic enrichment effects associated with this deposition are well known and managed to ensure environmental sustainability. However, the far-field effects that may be associated with the release of aquaculture waste material are poorly understood, partly because it is difficult to predict accurately the dispersion of wastes. Additionally, once wastes are moved from the immediate vicinity of a farm site, it is difficult to distinguish among deposits coming from farm activities, industrial sources, and natural sources.

To monitor, and if necessary, regulate, the far-field effects of aquaculture wastes, it is necessary to be able to identify what material originates from farm sources and where these wastes are transported. A limited number of sensitive detection tools (sediment-free sulfides and geo-normalized trace-metals) are currently available to environmental monitoring programs for making such identifications. Research has shown that aquaculture waste material (fish feed and faeces) has a trace-metal signature that can be distinguished from that of naturally-occurring trace-metals. It is proposed that the geo-normalization of trace-elements may identify depositional "hot spots" and track transport pathways to determine the fate of farm waste material.

This PARR project will focus on running a preliminary analysis on archived benthic data sets collected previously by the BC Ministry of the Environment and DFO. These datasets will support a region-wide assessment of aquaculture-derived trace-metal signature under various oceanographic, bathymetric, and operational settings.

APR. 2012 – MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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ENVIRONMENTAL INFORMATION SYSTEM FOR AQUACULTURE, PHASE 2

Canadian salmon farmers are collaborating to improve environmental data management and sharing, ensuring a high level of accuracy, and reducing regulatory reporting costs. This project, led by the BC Salmon Farmers Association, will deliver information technology that will also be directly relevant to DFO's industry reporting requirements.

In the first phase of this project, an improved BC fish-health database was launched, and a steering committee was setup to facilitate national discussions on the user needs for common fish-health information technology infrastructure. The improved fish-health database now provides efficient data upload and exchange. In addition a National Aquaculture Fish Health Data Management Framework Workshop was held January 2012. Phase 2 of the project will build on this infrastructure by standardizing and optimizing regulatory reporting through the database, standardizing and including diagnostic data in the database, and optimizing efficiencies of workflows.

These activities will result in fish-health management being enhanced in BC, thereby improving industry health management tools, enhancing industry productivity and operating efficiency as well as reducing operating costs. All of these factors are important contributors to improved environmental performance and long term industry sustainability.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Hatfield Consultants

PROJECT LEAD: Mary Ellen Walling (BC Salmon Farmers Association)

PROJECT TEAM: David Minato, Martin Davies, Jason Suwala, John Galambos (BC Salmon Farmers Association)

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ASSESSING THE VALUE OF BIVALVE MEAT AS AN INDICATOR OF ECOSYSTEM HEALTH

Study area and location of monitoring stations of oysters (circles) and mussels (triangles) in Prince Edward Island and New Brunswick (Eastern Canada). *Photo: Ramon Filgueira (Dalhousie U.)*

The purpose of this project is to assess the value of bivalve meat yield as a simple and cost-effective indicator of ecosystem change. The underlying rational is that drop in meat size and weight below natural bounds signals that the most important filter-feeders in the system (i.e., the bivalves in culture) are having a negative feedback on themselves and presumably other secondary producers in the environment. Conceptually the intent is to avoid a "tipping point", where the resilience is exceeded and the system reorganizes, compromising ecosystem functioning and consequently ecosystem services.

The project is divided into 2 phases. Firstly, a descriptive analysis of the available datasets and an evaluation of the potential of meat yield as an indicator of ecosystem change will be undertaken. If preliminary results conclude that meat yield could be successfully used as an indicator of ecosystem change, a second phase of the project will be considered to establish a quantitative regulatory framework for the management of shellfish farming.

NOV. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT LEAD: Ramon Filgueira (Dalhousie U.); Luc Comeau (DFO)

PROJECT TEAM: Thomas Guyondet, Thomas Landry (DFO)

COLLABORATORS: Jon Grant (Dalhousie U.)

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EVALUATING *BEGGIATOA* AND OPC AS INDICATORS OF BENTHIC HABITAT CONDITIONS ON HARD OCEAN SUBSTRATES USING VISUAL DATA COLLECTED SEASONALLY AT NEW FINFISH AQUACULTURE SITES AND NEAR THE END OF PRODUCTION AT ESTABLISHED SITES

The overall purpose of this project is to evaluate *Beggiatoa* (a type of aquatic bacteria) and OPC (Opportunistic Polychaete Complexes) as potential indicators of deposition around finfish aquaculture sites located over hard ocean substrates for HADD (*harmful alteration, disruption or destruction of fish habitat*) determinations. Four approaches will be used: 1) statistical relationships will be determined among and between potential indicators, physical parameters (e.g., substrate type) and production level by sampling along transects extending from cages, at site level (production level effects) and sample station level (for finer scale patterns); 2) physical influences on *Beggiatoa* and OPC cover will be determined by testing relationships between observations in baseline data and data collected for the first investigation; 3) differences in observations at the cage edge and at more distal locations will be determined by comparing the results of the first investigation to those from data collected at the cage edge post-production; and 4) temporal relationships among *Beggiatoa* /OPC (plus other components of benthic communities) and organic input will be determined by monitoring organic enrichment and benthic communities over time at new finfish aquaculture sites. Seasonal changes to the benthic community will also be determined by monitoring reference sites.

JULY 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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INFLUENCE OF EASTERN OYSTER AQUACULTURE OVERWINTERING ON EELGRASS

Eelgrass (*Zostera marina*) provides fish habitat to numerous commercial fish species and is considered an Ecologically Significant Species (ESS) in Atlantic Canada. There are concerns that various activities related to oyster aquaculture are causing disturbance and alteration to eelgrass beds. One such practice, which occurs in the southern Gulf of St. Lawrence, is the benthic over-wintering of oyster bags. During the open water seasons, oysters are cultured in plastic mesh bags attached to long lines floated at the water surface. However, in this area where surface waters typically freeze, the bags are moved to the deepest part of the lease and dropped to the bottom where they can be left to overwinter or accessed through the ice for harvesting. Since the substrate of these lease areas is often characterized by eelgrass habitat, concern has been expressed by habitat regulators about physical damage that may be caused to eelgrass by these over-wintering activities.

This project is designed to assess the potential impact that the practice of overwintering oyster bags may have on eelgrass beds in the southern Gulf of St. Lawrence and will provide the opportunity to study eelgrass winter ecology and its susceptibility to disturbance during this period. The project will also examine the environmental performance of a newly developed bivalve aquaculture technology (*Horizontal Rope Floating Rack system*). This floating rack system rests on the substrate while ensuring the oysters themselves do not make contact with the benthos. We hypothesize this system will cause less benthic disturbance than current culture structures while also lessening oyster mortality. The results of this study are expected to contribute to scientific advice for regulatory decisions and best management practices to minimize and/or mitigate potential negative impacts of oyster aquaculture on eelgrass habitat.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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PROJECT TEAM: Marc Skinner (Stantec Consulting Ltd./ CRI); Monica Boudreau (DFO)

COLLABORATORS: André L. Mallet (L'Étang Ruisseau Bar Ltée)

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COMPARING THE IMPACT OF BOTTOM AND SUSPENDED OYSTER CULTURE ON BAY-SCALE FOOD RESOURCES

Bivalves, such as mussels and oysters, are filter feeders that extract naturally occurring food, such as plankton, from the water. Their culture does not require the addition of feed; however, growth depends on the availability of food in the environment. When farming these species, special care must be taken to ensure that the number of cultured animals does not exceed carrying capacity of the area. Exceeding carrying capacity will ultimately result in decreased growth of the cultured animals and could potentially impact other components of the ecosystem.

Oyster (*Crassostrea virginica*) aquaculture is gradually evolving from the traditional use of the benthic environment (bottom culture) to suspension culture, where the animals are grown in or on structures suspended in the water column where higher growth rates are often observed. The Foxley/Trout River system in Prince Edward Island (PEI) is considered to be one of the more heavily utilized oyster producing areas on the island. Some oyster culturists in this area have experimented with this new approach and are requesting to convert their bottom leases to suspended leases. However, both industry and regulators recognize the need to evaluate the ecological impact of growing oysters in the water column before lease conversions are granted. Since suspended culture holds a greater density of shellfish than bottom culturing, food availability may be an issue if all leases were to become suspended culture.

This project is designed to address the issue of carrying capacity by examining the extent to which the diet of bottom and suspended oysters overlap; comparing the filtration rates of oysters from the two culture types (bottom and suspended); and incorporating this information into a simple bay-scale model to quantify the impact of different culture scenarios on available food resources.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

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TOP: Suspended oyster farm on the Foxley/Trout River system, PEI. BOTTOM: Oysters on the sea floor in an eelgrass bed. *All Photos: Luc Comeau (DFO)*

EXPLORATION OF METHODOLOGIES FOR ENVIRONMENTAL EFFECTS MONITORING OF FINFISH AQUACULTURE SITES IN SANDY BOTTOM ENVIRONMENTS WITH NATURAL DISTURBANCES: SHELBURNE, NS

The effect that aquaculture waste material (feed and faeces), generated by finfish operations, may have on the environment beneath open netpen sites is a concern both for regulators and industry and is closely regulated in all areas of Canada. Existing regulatory modelling tools (DEPOMOD) and sampling techniques (cores and light weight grabs) used to predict and monitor waste deposition and benthic impacts have generally been developed for use in areas with muddy bottoms. Questions have been raised about the applicability of these tools with different substrates, such as rocky or sandy bottoms, or if they need to be refined for use in these areas.

Shelburne, NS is a developing aquaculture area where the benthic environment is sandy and highly disturbed and, as such, the benthic cores and grabs usually used for regulatory sampling do not work well. Modelling deposition in this area is also challenging because very limited benthic and oceanographic information is available to calibrate models and, problematically, the dynamic environment requires that models account for the resuspension and movement of deposited wastes.

The purpose of this project is to test several benthic sampling approaches (grab samplers, ROVs, still image and video camera systems, acoustic echo sounder and side-scan sonar systems) to identify the best method for regulatory environmental sampling in dynamic, sandy bottom areas. Additionally, to improve modelling predictions, oceanographic conditions including water currents, wave activity, and water column profiling will be monitored during the fall-winter disturbance season. In addition, a benthic characterization study will be conducted to better categorize the benthic environment (e.g., sediment grain size, organic matter, sulphide content).

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT TEAM: Blythe Chang, Fred Page, Mark McLean, Ed Parker, Herb Vandermuelen, Sara Scouten (DFO)

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ASSESSING AND MITIGATING RISK FROM A DIVERSIFYING AQUACULTURE INDUSTRY: THE POTENTIAL FOR INTERACTION BETWEEN ESCAPEE AND WILD ATLANTIC COD

As with any industry, there are environmental concerns associated with aquaculture. These include pollution, disease and parasite transmission, and interactions with wild fish when farmed individuals escape. Our knowledge of escapee/wild fish interactions is focused on salmonids, but diversification of the industry has resulted in culture of other species that behave very differently from salmon. Atlantic Cod, for instance, interact much more with sea-pen netting and escape at much higher rates than salmon. Cod will also spawn inside the cage, releasing fertilized eggs into the environment even when the cultured animals do not escape.

Our project was based at Memorial University and had both local and European collaborators. It focused on what motivates cod to escape from cages, where they went once they escaped, and how they interacted during spawning with wild cod. The ultimate goal was to ascertain areas of particular environmental concern and identify mitigation opportunities before industry practices become entrenched.

SUMMER 2009 – ONGOING

FUNDED BY: Natural Sciences and Engineering Research Council of Canada (NSERC) **CO-FUNDED BY:** DFO; Fish Food & Allied Workers

PROJECT LEAD: Ian Fleming, Craig Purchase (MUN)

PROJECT TEAM: Ian Fleming, Craig Purchase (MUN); Edward Trippel, John Brattey (DFO)

COLLABORATORS: DFO; Fish Food & Allied Workers; SINTEF/EU Consortium; Ocean Tracking Network (Dalhousie U.); Cod Genome Project

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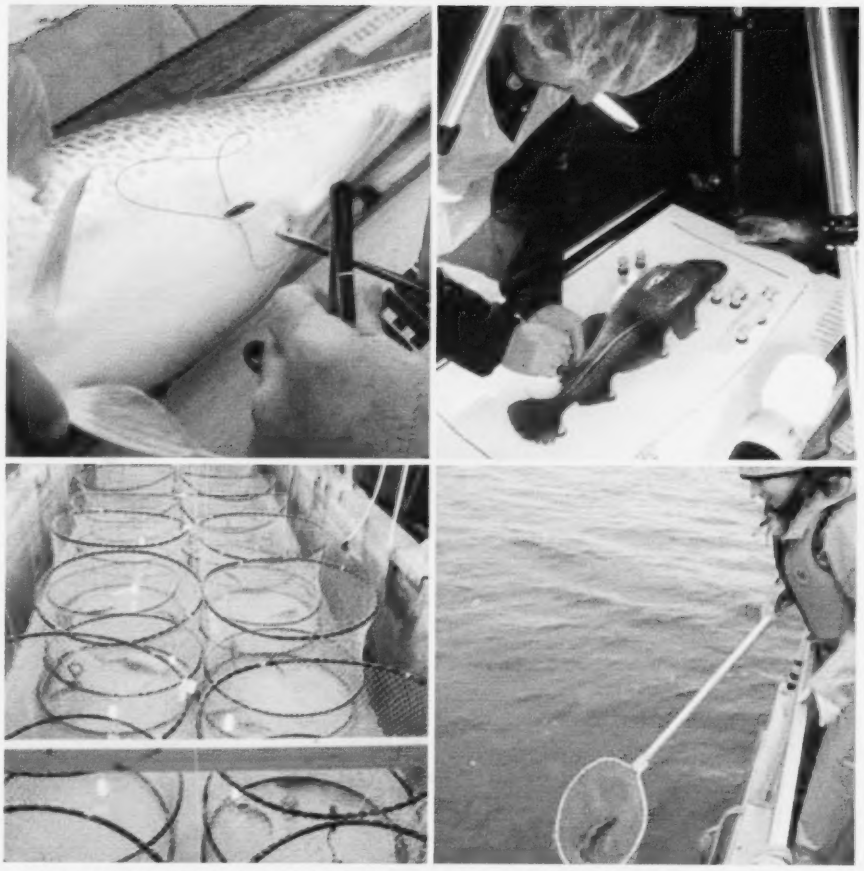

CLOCKWISE FROM TOP LEFT: Tying sutures after implanting an acoustic tag. *Photo: Emily Zimmermann (MUN).* Cod morphology study. *Photo: Brendan Wringe (MUN).* Net biting experiments. *Photo: Emily Zimmermann (MUN).* Releasing a tagged cod in Bay Bulls (Emily Zimmermann) *Photo: Emily Zimmermann (MUN)*

DETERMINATION OF THE POTENTIAL SPATIAL OVERLAP AND INTERACTION BETWEEN COMMERCIAL FISHERIES (AMERICAN LOBSTER, SNOW CRAB) AND FINFISH AQUACULTURE ACTIVITIES IN CONNAIGRE BAY, NEWFOUNDLAND

There is rarely an opportunity to collect and compare ecological data before, during, and after a salmon farming site has been approved and under production. This four-year project will allow for the collection of environmental and biological data at two newly approved salmon aquaculture sites in Connaigre Bay, Newfoundland and Labrador — a bay that has not yet held salmon production sites. Pertinent data will be collected prior to the sites being established and during the full production cycle, as well as during the fallow period. In the siting area, there is particular concern for alterations to crab and lobster habitat and resulting changes in habitat utilization, as a result this research will also examine potential changes in the benthic environment that could potentially impact lobster and Snow Crab populations.

The ultimate goal of the research project will be to identify any measurable impacts caused by the introduction of fish farming on the commercial species currently harvested in Connaigre Bay.

The outcomes of this project will provide valuable information that will inform future site development initiatives and contribute to the sustainability of both fishing and the fish farming industry on the south coast of Newfoundland and Labrador.

AUG. 2012 – MAY 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon Inc.

PROJECT LEAD: Gehan Mabrouk (DFO)

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COLLABORATORS: Jennifer Woodland (Cold Ocean Salmon Inc.)

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VALIDATION OF DEPOMOD WITH A COMPARISON OF VISUAL TECHNIQUES FOR OBSERVING SPATIAL AND TEMPORAL VARIABILITY IN THE BENTHOS AT ACTIVE AND FALLOWED FINFISH SITES IN NEWFOUNDLAND

Most finfish aquaculture sites in Newfoundland are located over deep waters (>100 m) with hard substrates and low currents which results in high monitoring costs relative to other Atlantic provinces. This is due to the need for more expensive equipment and technology use in gaining information about conditions of the sea floor. The current monitoring program was based on the assumption that deep water sites with hard substrates are not depositional; however, organic particulate have been found to accumulate at some sites. In this project, techniques are being investigated that will provide a better understanding of the physical and biological processes near finfish aquaculture sites over hard substrates.

A model of particle dispersion, DEPOMOD, is being evaluated as a monitoring tool for depositional processes at finfish aquaculture sites in Newfoundland. Data collection for model inputs has involved the deployment of sediment traps and current meters. The response of the benthic community to organic inputs is also being studied through the use of various methods of underwater video sampling (drop cameras, remotely operated vehicles, time-lapse cameras).

MAY 2010 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon Inc.; Northern Harvest Sea Farms

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EVALUATION OF THE FVCOM MODELLING SYSTEM TO MAP THE FAR-FIELD DISPERSAL OF AQUACULTURE WASTE

Particulate aquaculture wastes, such as fish faeces and feed pellets, can accumulate beneath and near farm operations. Near-field waste accumulation is relatively well understood and can be predicted using depositional modelling tools such as DEPOMOD. In contrast, the far-field distribution and potential environmental effects of particulate waste and material that is re-suspended from beneath aquaculture cages is more complex and difficult to predict. With increasing concerns over the potential far-field effects of aquaculture, including cumulative effects and ecosystem interactions, it is necessary to be able to predict the quantity and range of this dispersal. The goal of this study is to develop a coupled hydrodynamic-sediment transport model capable of mapping the far-field dispersal of aquaculture wastes from a single farm site in southwest New Brunswick using the Finite Volume Coastal Ocean Model (FVCOM).

The hydrodynamic component of the FVCOM model has been used and validated for ocean currents in southwest New Brunswick. Additionally, the particle tracking component of this model, for use with passive particles, has been successfully employed to infer the movement of and the dispersal of dye which is analogous to therapeutant transport. The fully coupled hydrodynamic-sediment transport model will add active particle transport by defining variables such as settling velocity, critical erosion shear stress, and erosion rate, which are necessary to predict the deposition and transport of aquaculture waste. To develop the model, parameters obtained from previous and current research on the transport dynamics of aquaculture waste will be used. The model will be validated using site specific data collected from a salmon aquaculture site in southwest New Brunswick.

The success of this proof-of-concept modelling project will help facilitate improved predictions regarding the transport of wastes generated from aquaculture operations and consequently the potential environmental interactions associated with aquaculture operations in the far-field.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT TEAM: Brent Law, Yongsheng Wu, Terri Sutherland (DFO)

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QUANTIFYING BENTHIC TRANSPORT OF AQUACULTURE WASTE MATERIAL FOR INCLUSION IN PREDICTIVE MODELS

A national strategy for understanding and predicting aquaculture waste transport is required by DFO Habitat Management and Ecosystems and Fisheries Management. Current models are unable to predict aquaculture waste transport because of the inability to measure the cohesive nature and transport properties of faecal material, waste pellets, and their interaction with sediment in suspension and on the seabed. The purpose of the project is to develop a data set of variables that can be used to initialize coupled hydrodynamic-sediment transport models to predict aquaculture waste resuspension and transport for use nationally. The first goal is to create a data matrix of transport coefficients of both finfish and bivalve aquaculture waste material to predict the transport capability of the material when resuspended. A variety of feed pellet types and finfish and shellfish faeces will be exposed to a range of seabed types, simple to complex, under controlled hydrodynamic conditions. This matrix will be derived from both laboratory and field studies. The second goal is to collaborate with the Scottish Association for Marine Science to initialize a beta-version of DEPOMOD that will incorporate a flexible resuspension module suitable for Canadian waters and to discuss model parameters and initializations of FVCOM with modelers at DFO.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT LEAD: Terri Sutherland, Brent Law (DFO)

PROJECT TEAM: Mike Foreman, Fred Page, Yongshen Wu, March Klaver (DFO); Chris Cromey, Scottish Association for Marine Science, U.K.; Carl Amos (University of Southampton, U.K.)

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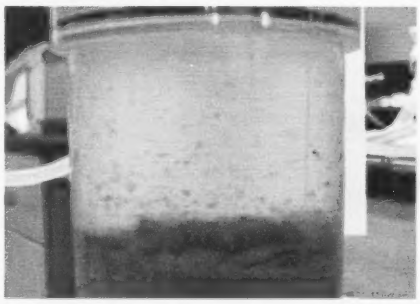

In-laboratory erosion measurements of mussel aquaculture waste using a Gust microcosm erosion chamber and a sandy seabed. Applied bed shear stress of 0.08 Pa is strong enough to mobilize the waste material and re-suspend large aggregates. *Photo: Particle Dynamics Lab, BIO (DFO)*

CIMTAN

Can filter-feeding bivalves ingest planktonic sea lice, leading to reduced sea lice numbers on cultivated salmon?

Quantifying the capture and conversion efficiencies of species being considered for organic extraction in open-water IMTA systems

A variation on the IMTA theme for land-based, freshwater aquaculture operations: the development of freshwater IMTA for salmon and aquatic plants

Quantifying temporal and spatial patterns of nutrient and organic particle plumes in IMTA systems — the basis for system design

Extensive versus intensive IMTA systems — hydrographic influences and the implications to infrastructure design and operational efficiency

Design and pilot-scale testing of new infrastructure components, including integration of energy alternatives to increase operational efficiencies

Social implications of IMTA

Use of Blue Mussels as a biological means to reduce the horizontal transmission of *Loma salmonae* (agent of microsporidial gill disease of salmon)

Cultivation of complementary inorganic extractive species for increased system performance

Presence, effect of and bioaccumulation of therapeutants in polychaetes

Economic and financial modelling of IMTA

Optimizing IMTA species component stocking densities and infrastructure orientation to maximize overall system efficiency

Evaluating the performance of proposed and existing IMTA sites using an ecosystem modelling approach

Quantifying energy and nutrient dispersal and scales of influence on wild species from open-water IMTA sites

Mathematical modelling for open-water IMTA – Developing tools to support system design and measures of sustainability

The role of microbes in the nutrient recycling of organic material from IMTA sites

CIMTAN: THE CANADIAN INTEGRATED MULTI-TROPHIC AQUACULTURE NETWORK

The Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN) is a NSERC strategic network that was initiated in 2010. It integrates academic knowledge and industrial know-how in a formal network that combines a strategic approach, inter-disciplinary, multi-institutional, and multi-sectoral strengths, and shared expertise to develop and advance innovative and improved environmentally-responsible aquaculture technologies and practices. The aim of CIMTAN research is to ecologically engineer systems for increased environmental sustainability (ecosystem services and green technologies for improved ecosystem health), economic stability (improved output, lower costs, product diversification, risk reduction, and job creation in coastal and rural communities), and societal acceptability (better management practices, improved regulatory governance, nutrient trading credit incentives, and appreciation of differentiated and safe products).

CIMTAN is providing inter-disciplinary research and development and highly qualified personnel (HQP) training in the following linked areas: 1) ecological design, ecosystem interactions, and biomitigative efficiency; 2) system innovation and engineering; 3) economic viability and societal acceptance; and 4) regulatory science; all of which will facilitate the commercialization of IMTA in Canada. The Network is organized into three linked Domains reflecting the four linked areas identified above: Domain 1 (environmental system performance and species interactions) is comprised of 10 projects of an environmental nature; Domain 2 (system design and engineering) is comprised of 4 projects of an engineering nature; and both are linked by the cross-cutting Domain 3 (economic analyses and social implications, with 2 projects), as biological, environmental, biotechnological, and engineering issues are always linked to economic aspects and social acceptability. Each Domain is co-led by a scientist at an academic institution and one at a DFO laboratory.

The Network consists of 27 scientists from 8 universities, 6 federal government laboratories (DFO), 1 provincial government laboratory (New Brunswick Research and Productivity Council), and 4 industrial partners: Cooke Aquaculture Inc., Kyuquot SEAfoods Ltd., Marine Harvest Canada Ltd., and Grieg Seafood BC Ltd. who joined the Network in April 2012. The Network is hosted by the University of New Brunswick in Saint John (UNBSJ). Training of HQPs is a very high priority for CIMTAN, with the training of 81 completed or in progress out of the 114 planned for the entire life of the Network: 35 summer students, 18 MSc, 2 MASc, 7 MA/MRM graduate students, 3 PhD students, 6 postdoctoral fellows, 9 technicians, and 1 research associate. There has been significant mobility of HQPs and investigators within projects and between east and west coast projects, as it is important to develop a versatile and inter-disciplinary workforce if we want the scientists, policy influencers, decision makers, regulators and industrialists of tomorrow to be innovative and build a more diversified and responsible aquaculture sector.

One of the incremental benefits of a network approach includes access to an enlarged equipment and tool inventory at academic institutions and government laboratories. Conducting experimental research on the east and west coasts in a concerted manner allows the acquisition of complementary and compatible information, hence increasing research outputs and outcomes and reducing redundancies in research efforts. Moreover, by gathering data on a wide geographical and temporal basis, with a wide range of environmental conditions, more generalized trends may be discerned, which will allow for the design of more robust systems and policies, taking into consideration both the universality of some aspects and the regional specificity of others.

At the mid-point of its tenure, CIMTAN has produced a diversified array of documents and media directed at different audiences: 22 refereed journal papers, 15 refereed conference publications, 7 book chapters, edited 1 issue of the Bulletin of the Aquaculture Association of Canada, 13 non-refereed publications, 132 abstracts, 17 lectures given at academic institutions, 1 technical report, 1 Wikipedia article, 7 YouTube videos, 15 CIMTAN Snippets newsletters, and 389 media contacts (magazine articles, newspapers/radio/TV interviews and documentaries).

The following research articles in this section describe each of the initial 14 projects of CIMTAN and two new projects, begun in September 2012:

- Evaluating the performance of proposed and existing IMTA sites using an ecosystem modeling approach;
- A variation on the IMTA theme for land-based, freshwater aquaculture operations: the development of freshwater IMTA for salmon and aquatic plants.

JAN. 2010 – DEC. 2014

FUNDED BY: NSERC Strategic Network Program **CO-FUNDED BY:** DFO; UNB; NBRPC; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

PROJECT LEAD: Thierry Chopin (UNBSJ)

PROJECT TEAM AND AFFILIATIONS: Thierry Chopin, Bruce MacDonald, Adrian Hamer, Meryl Coes (UNBSJ); Gregor Reid (UNBSJ/DFO – SABS); Shawn Robinson (DFO – SABS); Maycira Costa (UVic); Chris Pearce (DFO – PBS); Duncan Knowler (SFU); Saleem Rahman (DFO – EAS)

COLLABORATORS AND INDUSTRY PARTNERS: Fisheries and Oceans Canada; The New Brunswick Research and Productivity Council; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

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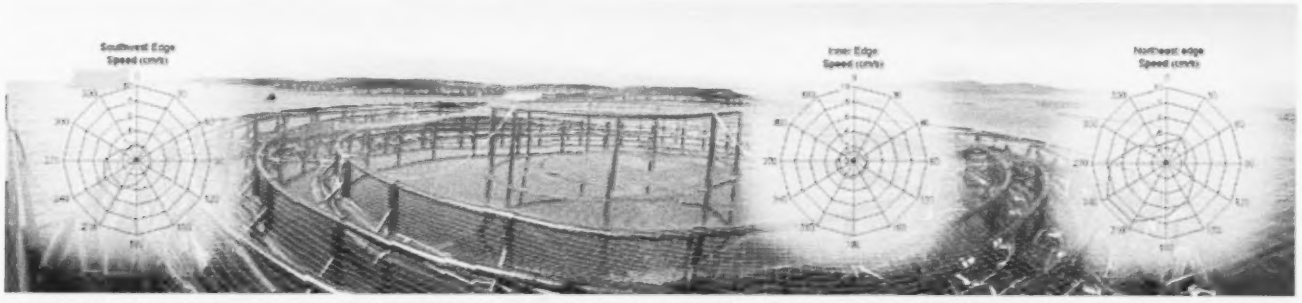
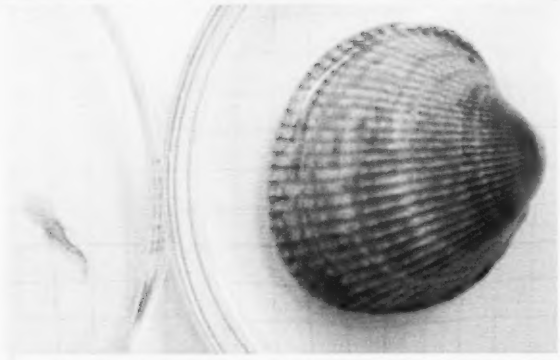


Polar plots of relative current speeds and headings measured at a 5 m depth over several tidal cycles. Plots are shown at their relative locations within a mussel polar circle raft at an IMTA site in the Bay of Fundy. These data help to determine the frequency of particle delivery from Atlantic Salmon cages and how current velocities, around Blue Mussel socks at different locations within the polar circle raft, may affect particle clearance and particle depletion rates of co-cultured shellfish. *Photo: Gregor Reid (UNBSJ/DFO – SABS)*

CAN FILTER-FEEDING BIVALVES INGEST PLANKTONIC SEA LICE, LEADING TO REDUCED SEA LICE NUMBERS ON CULTIVATED SALMON?



TOP: Janis Webb holding a scallop next to her experimental set up at the DFO Pacific Biological Station in Nanaimo, British Columbia. *Photo: Julie Vanderbor*
LEFT: Sea lice and Basket Cockle on separate petri dishes. *Photo: Janis Webb (DFO)*

Filter-feeding shellfish suspended at salmon farms might reduce sea lice infections of the fish and the need for chemotherapeutants if bivalves consume sufficient quantities of sea lice larvae from the water column. A laboratory study, involving Basket Cockles, Pacific Oysters, Pacific Scallops, and mussels and examining the effects of temperature, presence/absence of phytoplankton, and bivalve size, clearly demonstrated that all the tested species consumed quantities of sea lice larvae under the various conditions. The live larvae were offered to the shellfish at a much greater density than might occur at a salmon farm. Of the conditions tested, only size (tested with oysters and scallops) had a significant effect on the quantity of sea lice larvae ingested; larger scallops and oysters consumed more larvae than smaller sizes of the same species. This laboratory phase of the CIMTAN project is now complete. Based on the knowledge gained, field trials have begun at a BC salmon farm where oysters and mussels have been suspended immediately beside salmon net pens to determine whether they may, indeed, act as biological controllers of larvae, reducing sea lice infections on the fish.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Chris Pearce (DFO – PBS)

PROJECT TEAM: Stephen Cross, Janis Webb (UVic); Simon Jones (DFO – PBS); Shawn Robinson (DFO – SABS); David Stirling (VIU)

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QUANTIFYING THE CAPTURE AND CONVERSION EFFICIENCIES OF SPECIES BEING CONSIDERED FOR ORGANIC EXTRACTION IN OPEN-WATER IMTA SYSTEMS

This project evaluates the potential for several species of invertebrates to act as extractive species for IMTA on both the east coast and the west coast of Canada and determines the digestibility coefficients of Sablefish (*Anoplopoma fimbria*). In British Columbia (BC), a number of marine invertebrate species are candidates for use in open-water IMTA with Sablefish. These include both filter-feeding bivalves (e.g., cockles and mussels), which would consume the finer suspended particulates from the finfish culture component, and deposit/detrital feeders (e.g., sea cucumbers, sea urchins, and prawns), which would feed on the heavier-settleable solids. The following candidate species were tested for their ability to consume Sablefish faeces and uneaten Sablefish feed in laboratory feeding trials: Green Sea Urchin (*Strongylocentrotus droebachiensis*), Basket Cockle (*Clinocardium nuttallii*), Blue Mussel (*Mytilus edulis*), Spot Prawn (*Pandalus platyceros*), and California Sea Cucumber (*Parastichopus californicus*). In New Brunswick, the Orange-footed Sea Cucumber (*Cucumaria frondosa*) was assessed for its ability to absorb waste food and faeces at Atlantic Salmon (*Salmo salar*) IMTA sites. All six species tested could successfully extract organic material from aquaculture wastes and information on the characteristics of the faeces egested by the candidate species will provide information on bio-deposition rates and input data for models predicting the environmental impact of IMTA. Digestibility coefficients in Sablefish were found to be greater when the fish were reared at warmer temperatures and fed more frequently.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Bruce MacDonald (UNBSJ)

PROJECT TEAM: Stephen Cross (UVic); Chris Pearce, Dan Curtis (DFO – PBS); Shawn Robinson (DFO – SABS); Gregor Reid (UNBSJ, DFO – SABS); Helen Gurney-Smith (VIU – CSR); Shannon Balfry (UBC – Vancouver Aquarium); Emily Nelson, Kurt Simmons (UNBSJ); Lindsay Orr (UVic); Steven Pace (UBC)

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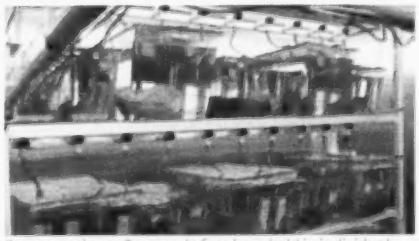

Sea cucumbers, *Cucumaria frondosa*, held in individual flow-through containers in a laboratory absorption efficiency experiment. Photo: Lindsay Orr (UVic)

A VARIATION ON THE IMTA THEME FOR LAND-BASED, FRESHWATER AQUACULTURE OPERATIONS: THE DEVELOPMENT OF FRESHWATER IMTA FOR SALMON AND AQUATIC PLANTS

The IMTA concept is not confined to open-water, marine systems using finfish for the fed component and seaweeds and invertebrates for the extractive components. It has to be conceived as an extremely flexible concept: a central/overarching theme on which many variations can be developed. Its principles can also be applied to land-based, closed-containment and freshwater systems (sometimes called aquaponics). So far, we have been working on developing IMTA for the seawater grow-out phase of Atlantic Salmon (*Salmo salar*) aquaculture. However, if salmon spend between 1.5 to 2 years in seawater pens, it is after they have spent between 9 and 18 months in freshwater hatcheries. Freshwater IMTA (FIMTA) is the combination of animal aquaculture with plant hydroponic cultivation. In such systems, effluents become nutrients for the plants instead of potentially accumulating or being released downstream from the operation. From an environmental perspective, it is the same strategy of recapturing lost nutrients and energy and converting them into biomass of commercial value. Of course, the extractive species and infrastructures will be different from what we have developed so far at open-seawater sites. From an economic and marketing perspective, it will also be most interesting to develop an overall system where salmon will be IMTA-produced from the egg to the plate, as this will help considerably in the certification scheme and in obtaining premium prices. We are presently investigating the potential for developing FIMTA systems for the Atlantic Salmon hatcheries operated in NB by Cooke Aquaculture Inc. Both flow-through and recirculating facilities are being assessed to design the most appropriate FIMTA systems, based on water quality and flow, nutrient concentrations and bioavailability, temperature, light, space availability, plant candidates, and economic viability.

SEPT. 2012 – DEC. 2014

PROJECT LEAD: Thierry Chopin (UNBSJ)

PROJECT TEAM: Hamid Khoda Bakhsh, Stacy Murray (UNBSJ)

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EXTENSIVE VERSUS INTENSIVE IMTA SYSTEMS — HYDROGRAPHIC INFLUENCES AND THE IMPLICATIONS TO INFRASTRUCTURE DESIGN AND OPERATIONAL EFFICIENCY

Di Wan with a conductivity, temperature, and depth (CTD) instrument. *Photo: Di Wan (UVic)*

This project is examining flow patterns in relation to farm infrastructure by observing localized tidal influences, effects of wind and impacts of the farm structure itself. To address this, circulation modelling in Kyuquot Sound is being developed focusing on: 1) a simulation for the period of February 22 to March 11, 2011 that included a major winter storm and; 2) an analysis of tidal behaviour and dissipation throughout the Sound. Together they have provided a better understanding of far-field influences on the infrastructure at the IMTA site. Wind and river discharge forcing fields are presently being assembled in the model since *in situ* data from a weather station started to be acquired. On the east coast, preliminary results of the effects of salmon cages and mussel socks on flow fields are showing some evidence of damping effect. From these results, a protocol identifying what and where to measure in relation to the mussel polar circle raft outflow has been developed. Further, data from dye dispersal experiments have identified a high degree of site specific variability of near and far field dispersal patterns.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Gregor Reid (UNBSJ/DFO – SABS)

PROJECT TEAM: Fred Page (DFO – SABS); Mike Foreman (DFO – IOS); Stephen Cross, Di Wan (UVic)

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QUANTIFYING TEMPORAL AND SPATIAL PATTERNS OF NUTRIENT AND ORGANIC PARTICLE PLUMES IN IMTA SYSTEMS — THE BASIS FOR SYSTEM DESIGN

On the west coast, this project is tracking the particulate plume dispersing from the fish cages at the Kyuquot SEAfoods Ltd. IMTA site with optical instrumentation and *in situ* biophysical data. Results are showing in-cage versus out-cage differences in particulate concentrations and in-cage increases in particulates with time after feeding. Similar optical work is underway in NB to understand the timing, magnitude, spatial extent and dispersion of particulate and dissolved nutrients. Detailed current speeds and headings are measured over different tidal cycles within mussel polar circle rafts to help determine the frequency of particle delivery from Atlantic Salmon cages and how current velocities around Blue Mussel socks, at different locations within the polar circle rafts, may affect particle clearance and particle depletion rates of co-cultured shellfish. For both coasts, hydrographic and biophysical data are being integrated into site specific models that will serve as tools for predicting organic and inorganic waste dispersion, selecting and designing efficient IMTA sites, and locating appropriately the extractive components of IMTA systems so that they can intercept the plumes. The project is further evaluating the use of the kelp *Saccharina latissima* as an *in situ* bioassay to delimit the inorganic nutrient plume associated with the Sablefish fed component.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Maycira Costa (UVic)

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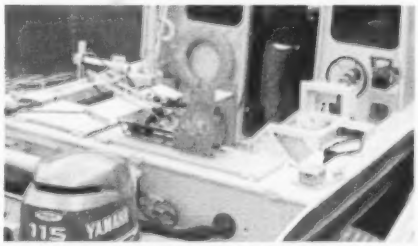

The Acrobat undulating sensor vehicle used in the search for organic particle fish waste plumes. *Photo: Stephen Cross (UVic)*

DESIGN AND PILOT-SCALE TESTING OF NEW INFRASTRUCTURE COMPONENTS, INCLUDING INTEGRATION OF ENERGY ALTERNATIVES TO INCREASE OPERATIONAL EFFICIENCIES

This project aims to investigate the potential for incorporation of renewable energy technologies into IMTA sites. The project is focused on the Kyuquot SEAfoods Ltd. (KSL) west coast IMTA site as a test location for the modelling, installation and testing of a renewable energy system. Model of the loads and measurements of the various renewable energy resources at the site were assembled, and the optimal energy system was determined to consist of a photovoltaic (PV) solar array with battery storage and a small diesel generator backup. The original system was to only power the winches on a moveable tram shellfish husbandry system, but recent analysis and consultation with KSL has expanded the system design to include motive power for the tram which is currently diesel operated. Final design work for a 'power trailer' to supply the full loads of the tram is ongoing, and when installed will include an array of sensors and equipment to monitor the performance of the PV-battery bank-genset system. The aim is to validate the system models while at the same time developing a modular and scalable renewable energy system for other IMTA sites.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Curran Crawford (UVic)

PROJECT TEAM: Stephen Cross, Eric Hoevenaars, Adam Gray (UVic); Thierry Chopin (UNBSJ)

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SOCIAL IMPLICATIONS OF IMTA

Shellfish aquaculture boat in Baynes Sound, BC. *Photo: Brian Kingzett*

Many coastal First Nations communities in BC are highly dependent on fisheries for their livelihoods. In response to declining wild stocks, some communities have engaged in fisheries enhancement programmes while others have developed commercial aquaculture businesses. The development of aquaculture, particularly finfish, within First Nations traditional territories, however, has become increasingly controversial. While some believe aquaculture can contribute to community social and economic development, others view it as a threat to traditional ways of life. The purpose of one of our projects is to improve our understanding of the concerns that different First Nations communities have with the development of shellfish and finfish aquaculture within their traditional territories, and to assess the role that IMTA could play in alleviating them. Another project is looking at the implications of the emergence of IMTA on the resilience and well-being of coastal community social-ecological systems. This project stems from the observation that IMTA initiatives will not arise in a vacuum and that any movement towards IMTA will involve an evolution from and/or an articulation with the existing industry. Moreover, the 'social acceptance' of any emerging aquaculture industry in BC will be a central issue. Accordingly, this inquiry explores the costs/benefits of the shellfish aquaculture industry for individuals living in Baynes Sound communities, and how those costs and benefits are distributed. Preliminary findings center on jobs provided, ecological impacts, noise and 'viewscape' pollution, alienation of other ocean uses, and a perceived lack of transparency in decision-making. The development of a sustainable IMTA industry will also require the development of effective governance structures. Accordingly, a third project is looking at the role of science, litigation, and public opinion in the contestation and negotiation of aquaculture governance in Canada, with particular emphasis on the implications for IMTA and industry legitimization.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Mark Flaherty (UVic)

PROJECT TEAM: Grant Murray, Linda D'Anna (VIU); Anna Belanger, Katie Tebbutt, Erin Latham (UVic)

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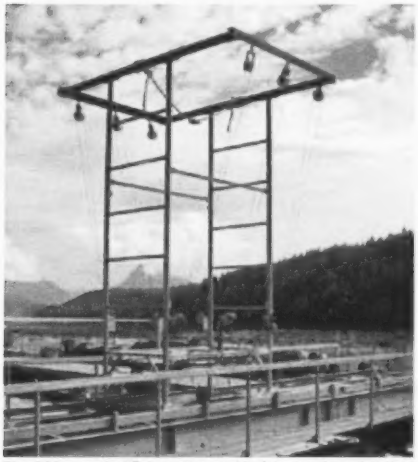

The SEAtram shellfish system and hoists developed at the Kyuquot SEAfoods Ltd. IMTA site. *Photo: Eric Hoevenaars (UVic)*

USE OF BLUE MUSSELS AS A BIOLOGICAL MEANS TO REDUCE THE HORIZONTAL TRANSMISSION OF *LOMA SALMONAE* (AGENT OF MICROSPORIDIAL GILL DISEASE OF SALMON)

In an effort to better understand and predict the interactions of disease causing agents within an IMTA setting, we have developed a laboratory based model system to study the fate of a microsporidian fish pathogen (*Loma salmonae*) within extractive shellfish species. *Loma salmonae*, which transmits between fish via an environmentally resistant spore, has been shown to be taken up by Blue Mussels (*Mytilus edulis*) where the spore can remain viable for at least three weeks. On the one hand, this suggests that mussels may serve a role in bioremediation, but it also cautions that shellfish may act as a reservoir for fish pathogens. Work is underway to more fully understand the dynamics of uptake, persistence, degradation, and the role of environmental variables, of this spore-producing pathogen within Blue Mussels. Results from these studies will provide aquaculturists with the necessary data to make the best choices regarding harvest times of different resources within an IMTA setting.

JAN. 2010 – DEC. 2014

PROJECT LEAD: David Speare (UPEI – AVC)

PROJECT TEAM: Jan Lovy, Nicole Guselle, Sarah McConnachie (UPEI – AVC)

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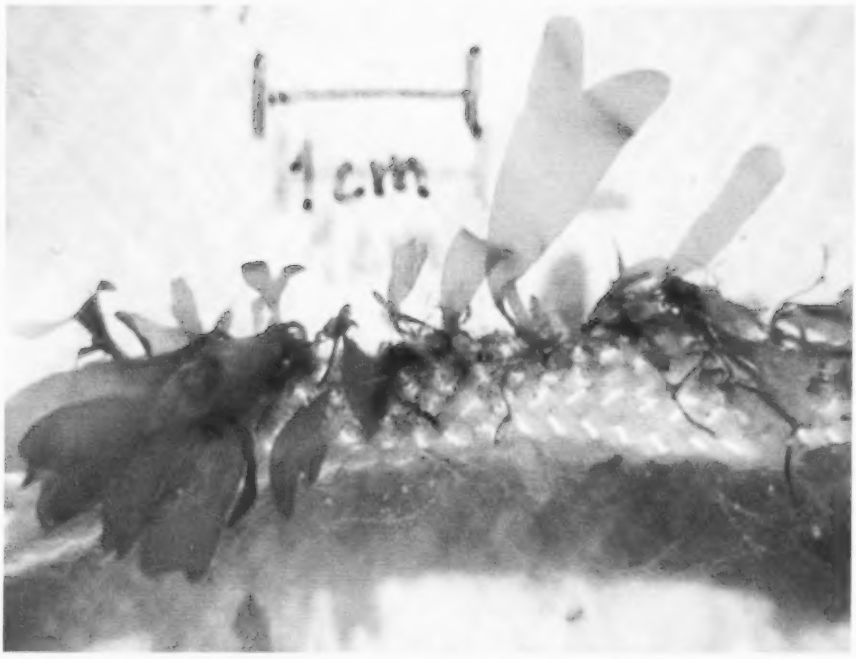
CULTIVATION OF COMPLEMENTARY INORGANIC EXTRACTIVE SPECIES FOR INCREASED SYSTEM PERFORMANCE



Cultivation on twine of young blades of the red alga *Palmaria palmata* (Dulse). *Photo: Constanza Chianale (UNBSJ)*

The inorganic extractive component of the IMTA system on the east coast has been the two kelps *Saccharina latissima* and *Alaria esculenta* since 2001. On the west coast, *Saccharina latissima* has been cultivated since 2007. These seaweeds are cultivated first in the laboratory, from September to November, and then at the sites from November to June/July. They need to be harvested in late spring/early summer before the erosion of the blades, and their fouling, compromise the harvest and quality of the derived products. The project is now investigating two new candidate species, *Palmaria palmata* (Dulse) on the east coast and *Ulva* sp. (Sea Lettuce) on the west coast, whose cycles and characteristics allow growth of the macroscopic stages during the summer to provide biomitigative biomass during that time of the year and, consequently, an overall increase of the inorganic biomitigative capacity of the IMTA systems. On the east coast, results accumulated so far have provided significant information on the biology of *P. palmata*, especially during fall and winter when very little information is available on this species. The optimal culture conditions and methods for the different stages of the life cycle are now being defined. Research is also underway to explore the use of seaweeds for partial substitution in fish feed formulations as alternate protein sources to fishmeal and land plant proteins. On the west coast, the potential of integrating *Ulva* sp. cultivation into the system design is underway to determine the level of production that could be generated within the infrastructure configuration, and the potential value of this seaweed as a feed additive to fish feeds.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Thierry Chopin (UNBSJ)

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A line of the cultivated kelp, *Alaria esculenta*, at an IMTA site in the Bay of Fundy, NB. *Photo: Thierry Chopin (UNBSJ)*

PRESENCE EFFECT OF AND BIOAC MULATION OF THERAP UTANTS IN POLYCHAETES

***Nereis virens*, an annelid worm,** is being considered as a co-extractive species in IMTA. Our research question relates to the potential for this species to be affected by pesticides and drugs used to treat Atlantic Salmon (*Salmo salar*) against infestations of sea lice. The drug emamectin benzoate (EB), while not lethal to *N. virens* at environmentally relevant concentrations, has been shown to affect burrowing behaviour and to reduce worm growth at those concentrations. These results suggest that the use of EB may negatively affect worms and limit their potential to be grown in IMTA situations. Testing is underway to determine how the pesticide, deltamethrin, affects *N. virens*.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Les Burridge (DFO – SABS)

PROJECT TEAM: Karen Kidd, Thierry Chopin, Geoff McBriarty (UNBSJ); Gregor Reid (UNBSJ/DFO – SABS); Shawn Robinson, Jordana Van Geest (DFO – SABS)

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30 – day experiment testing the effect of emamectin benzoate on the polychaete worm *Nereis virens*. The sediment used is silica sand from Fisher Scientific and the worms are from the Center for Cooperative Aquaculture Research in Franklin, Maine, USA. *Photo: Geoff McBriarty (UNBSJ)*

ECONOMIC AND FINANCIAL MODELLING OF IMTA

The Seattle Fishermen's Wharf Market was visited by Winnie Yip to conduct interviews with consumers. *Photo: Winnie Yip*

In 2012, this project completed one study and began two others. The former study investigated the willingness-to-pay for IMTA versus closed containment aquaculture (CCA) salmon in the USA Pacific Northwest. Results of a discrete choice experiment (DCE), combined with a latent class analysis (LCA), revealed a willingness-to-pay a price premium of 9.8% and 3.9% for IMTA and CCA, respectively. It was also revealed that 44.3% and 16.3% of the respondents preferred the adoption of IMTA and CCA to conventional salmon farming, respectively. A closer look at the LCA results identified price premiums for three distinct classes that ranged from 3.5% to 41.6% for IMTA, over conventionally produced Atlantic Salmon, while CCA enjoyed only modest price premiums. The new studies will implement a valuation study to value the ecosystem benefits of IMTA and evaluate nutrient credits as an incentive for the adoption of IMTA.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Duncan Knowler (SFU)

PROJECT TEAM: Winnie Yip, Kim Irwin, Stephen Crampton (SFU)

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EVALUATING THE PERFORMANCE OF PROPOSED AND EXISTING IMTA SITES USING AN ECOSYSTEM MODELLING APPROACH

This project recently began as a result of last year's CIMTAN technical workshop entitled "Spatial Modelling of Integrated Multi-Trophic Aquaculture Shellfish". While modelling efforts were progressing with the inorganic extractive component (e.g., kelps) and deposit feeders (e.g., sea urchins), it became clear that typical mass balance modelling techniques could not adequately capture system dynamics of co-cultured shellfish, on combined diets of natural and fish farm particulates, under the high temporal and spatial resolutions necessary to describe an IMTA system. Consequently, modifications to the Finite Volume Community Ocean Model (FVCOM) used by DFO are presently underway to enable operation at resolutions of 10 m while including fish cages as porous structures. In order to create an ecosystem model of an IMTA site and surrounding waters, FVCOM is being coupled to a shellfish scope for growth model, an algal sub-model and a fish sub-model. This approach will enable comparisons of shellfish produced in an IMTA system to production in a monoculture system, as a means to describe growth, nutrient abatement potential and facilitate management decisions.

SEPT. 2012 – DEC. 2014

PROJECT LEAD: Jon Grant (Dalhousie U.)

PROJECT TEAM: Gregor Reid (UNBSJ/DFO – SABS); Ramón Filgueira (Dalhousie U.)

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OPTIMIZING IMTA SPECIES COMPONENT STOCKING DENSITIES AND INFRASTRUCTURE ORIENTATION TO MAXIMIZE OVERALL SYSTEM EFFICIENCY

Understanding the dynamics of the flow of energy within an IMTA farm site will be important in helping practitioners design the systems of the future. Initially, IMTA developed independently on each coast, with integrated aquaculture systems being developed through modifications of existing infrastructures used for the culture of salmon within these regions. Although each regional development has examined the potential of IMTA on differing primary infrastructures (cage system configurations), the position of the various extractive species within the water column are similar and, in fact, dictated not by a desired husbandry-related need, but rather by their inherent and individual biological/ecological requirements (i.e., food availability, light, salinity, temperature, dissolved oxygen levels, water flows, wave exposure, etc.). The objectives of this project are to assess the characteristics of IMTA sites in BC and in NB, based on the existing studies to-date, and to determine what the potential future configurations might be through a combination of empirical studies and modelling. This project was designed to start later in the CIMTAN research cycle and is just now being initiated.

JAN. 2013 – DEC. 2014

PROJECT LEAD: Shawn Robinson (DFO – SABS)

PROJECT TEAM: Stephen Cross (UVic); Chris Pearce (DFO – PBS); Thierry Chopin (UNBSJ)

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Salmon aquaculture farm in the Bay of Fundy, NB. Polar circle cages are arranged over a square sub-surface grid configuration. *Photo: Cooke Aquaculture Inc.*

QUANTIFYING ENERGY AND NUTRIENT DISPERSAL AND SCALES OF INFLUENCE ON WILD SPECIES FROM OPEN-WATER IMTA SITES

Andrew Cooper and Jonathan Day installing PVC biocollecting plates at an IMTA site. *Photo: Gregor Reid*

New monitoring techniques need to be developed to quantify nutrient availability and dispersal from open-water IMTA sites in wild species. New work includes developing robust procedures (biocolonisation rates of PVC biocollecting plates and RNA/DNA ratio) to quantify correlations between biomass accumulation and instantaneous growth rates for colonising species such as the Vase Tunicate (*Ciona intestinalis*) and their proximity to fed aquaculture sites in the field and measured levels of feed exposure in the laboratory. In addition, we are investigating the possibility of using the variations in colour characteristics (chroma, hue and lightness measured with a colour spectrometer) in three seaweeds (the green alga *Ulva lactuca*, the red algae *Palmaria palmata* and *Porphyra purpurea*) as a faster and cheaper proxy for algal tissue nitrogen content determination to replace tedious and expensive chemical elemental analyses. These new methods will provide tools for CIMTAN to investigate further performance of IMTA with respect to nutrient recycling in the environment.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Andrew Cooper (DFO – SABS)

PROJECT TEAM: Thierry Chopin, Jonathan Day (UNBSJ); Shawn Robinson, Fred Page, Les Burridge (DFO – SABS)

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THE ROLE OF MICROBES IN THE NUTRIENT RECYCLING OF ORGANIC MATERIAL FROM IMTA SITES

This project is documenting the abundance of microbes in and around aquaculture sites, identifying the species mix present and measuring their metabolic activity on organic carbon for incorporation into the energy flow models of the IMTA sites. The work is occurring on IMTA sites in both the Bay of Fundy in NB and Kyuquot Sound in BC. Epifluorescent microscopic techniques using DNA stains are being used for enumeration; Denaturing Gradient Gel Electrophoresis (DGGE) is used for identification; and oxygen optode technology is used to measure oxygen uptake. The first phase of the research was to study the microbial populations in the water column. Results indicate that for respiration rates, organism counts, and species composition, there is more variation with depth than there is in horizontal distance from the site suggesting that the tidal mixing may be important in determining microbial densities around farms. The sampling will be continued over different seasons.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Shawn Robinson (DFO – SABS)

PROJECT TEAM: Ben Forward (NBRPC); Thierry Chopin, Brent Ellis, David Thumbi (UNBSJ); Terralynn Lander (DFO – SABS)

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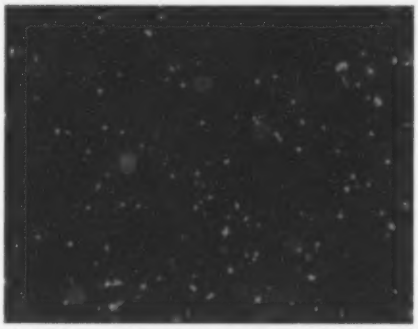

Digitized image of bacteria, on a 0.2 µm pore size filter, captured in the water column around an IMTA site. Bacterial nucleic acids have been stained with DAPI stain in order to visualize the number of organisms. *Photo: Terralynn Lander (DFO)*

MATHEMATICAL MODELLING FOR OPEN-WATER IMTA – DEVELOPING TOOLS TO SUPPORT SYSTEM DESIGN AND MEASURES OF SUSTAINABILITY

Developing IMTA practices aim to reduce the load of soluble inorganic (e.g., ammonia and phosphate) and solid organic nutrients (e.g., faeces and waste feed), while providing additional 'crops' for diversification. Quantifying the transfer and sequestration potential of nutrients in open-water IMTA is important for metrics of sustainability and bioeconomic decisions. This project investigates the efficiencies of species groups that sequester soluble inorganic nutrients (e.g., seaweeds), ingest organic particulates (e.g., shellfish) and those that ingest the larger organic material that can settle (e.g., deposit feeders). The way these groups interact with each other, as part of a complete system, and with the external environment, is presently being modelled. One example of the work currently under way is the investigation of the Green Sea Urchin (*Strongylocentrotus droebachiensis*) as a representative deposit feeder in IMTA systems. Sea urchin scope for growth on diets of kelp (*Saccharina latissima*; a natural food source), salmon feed and salmon faeces are being modelled with the results compared to actual growth. Respiration, excretion and absorption efficiencies are being measured for model inputs. Understanding the metabolic response and growth of the Green Sea Urchin on diets of salmon culture organics will guide future use of this species in IMTA systems to help reduce the amount of organic carbon reaching the benthos while providing additional potential for market diversification. Data from this and several other CIMTAN projects are used to supply IMTA model inputs. Some of these modelling efforts recently supported a Fisheries and Oceans Canada Canadian Science Advisory Secretariat peer-review on the organic extractive component of IMTA in the Bay of Fundy. Ultimately, project results will help us understand the system performance of open-water IMTA from a physical, biological and economic perspective, to assist with informed decision making at the farm and ecosystem management level.

JAN. 2010 – DEC. 2014

PROJECT LEAD: Gregor K. Reid (UNBSJ/DFO – SABS)

PROJECT TEAM: Bruce MacDonald, Thierry Chopin (UNBSJ); Tillmann Benfey, Nicole Leavitt (UNBF); Peter Cranford (DFO – BIO); Shawn Robinson (DFO – SABS); Margaret Quinton (U. Guelph)

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SHELLFISH: MUSSELS

Proof of concept of a scalable hatchery system using modular principles to increase production and survival for commercially important *Mytilus* species

Development of genomic health assessment tools for marine mussels (MYT-OMICS)

Design, installation and assessment of an innovative duck deterrent system to reduce predation of high value aquaculture *Mytilus* product and minimize duck mortality

Increasing vacuum packaging efficiencies in Blue Mussel processing

Arctic ice boom innovation for mussel farm protection

Improvement of quality and productivity associated with live Blue Mussel inspection through the installation of automated sorting equipment

An investigation of the lipid and fatty acid composition of the Blue Mussel with reference to palatability and taste during conditions of extended holding

New and innovative equipment for mussel processing industry

Comparison of the health and condition of cultured mussels from deep and shallow water sites in Newfoundland with reference to environmental conditions, condition index, physiological stress and lipid biochemistry

A project to develop and introduce automated, digital imaging technology to the grading process in Canadian mussel plants

Mussel larvae production enhancement by restocking mussel beds in Bassin du Havre-Aubert, Magdalen Islands

Evaluation of Blue Mussel processing plant holding systems in PEI

Genomic and physiological processes during the larval ontogeny of the Blue Mussel: impact of eicosanoid precursors

Technical-economic assessment of an integrated mussel post-harvest process

The Eider Spider: Development and experimental testing of a novel method to deter sea duck predation on mussel farms

Developing an innovative treatment system for Vase Tunicate fouling on cultured Blue Mussels

Impact of biotic and abiotic factors on the mechanical properties of the byssus of the Blue Mussel: a marketable biomaterial

Culture density, biomass-density relationship, and self-thinning in molluscs

Bioenergetics and mollusc food ingestion

PROOF OF CONCEPT OF A SCALABLE HATCHERY SYSTEM USING MODULAR PRINCIPLES TO INCREASE PRODUCTION AND SURVIVAL FOR COMMERCIALLY IMPORTANT *MYTILUS* SPECIES

Grant Hunt and the mussel larvae rearing tanks. Photo: Paul Simpson (Island Sea Farms)

Mussels are one of the fastest growing aquaculture products and the market demand far exceeds the current supply. Unfortunately, the lack of appropriate mussel seed has hindered industry development.

Island Sea Farms, a BC mussel production company has designed an innovative hatchery for mussels that will increase the production of seed by 50%. The reliable supply of additional seed will be used to stabilize and expand the BC industry through joint venture and other collaborative culture arrangements with current shellfish growers and First Nations. The innovative hatchery design uses green technologies that reduces energy requirements and improves environmental performance. The increasing demand for mussels and the relatively high value of the quality-controlled Island Sea Farms product presents an opportunity to market the new technology to interested growers in the BC shellfish industry as well as to mussel producers around the world.

Island Sea Farms has calculated the innovative modular hatchery will increase the production of mussel seed by 50%. The three modules (algal production, larval production, and nursery culture) have been constructed, integrated and optimized to create greater efficiencies and enhance output. Each module was designed to be constructed separately and scaled to production requirements allowing for incremental increase as required or over time.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Klahoose First Nation

PROJECT LEAD: Paul Simpson (Island Sea Farms)

PROJECT TEAM: Paul Simpson, Grant Hunt, Wendy Brown, Ingrid Niamath, Greg Steine (Island Sea Farms); Kathy Francis (Klahoose First Nation)

COLLABORATORS: Klahoose First Nation; World Fisheries Trust

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DESIGN, INSTALLATION AND ASSESSMENT OF AN INNOVATIVE DUCK DETERRENT SYSTEM TO REDUCE PREDATION OF HIGH VALUE AQUACULTURE *MYTILUS* PRODUCT AND MINIMIZE DUCK MORTALITY

Like other mussel aquaculture growing areas of the country, British Columbia has experienced significant losses due to marine diving duck predation. Current techniques for mitigating loss from duck predation are ineffective, frequently results in death of the duck, and often becomes a safety hazard for farm workers and divers. Island Sea Farms has developed an innovative duck predator deterrent system to reduce predation of farm raised mussels and to minimize harm to ducks.

The innovative Duck Deterrent System was designed with three parts — an unique net system that envelopes groups or single rafts with protection under the rafts as well as on the sides, a specially designed net deployment and retrieval platform to efficiently handle the net envelopes, and a net maintenance and cleaning system, re-purposed from the salmon farming industry, to remove heavy bio-fouling. It is the combination of these three elements that make it possible to address all of the current problems.

Predation by diving ducks is the main problem for the mussel culture industry in BC and many other areas of Canada. The use of this innovative system will remove a constraint to sustainable production while increasing the competitiveness of the Canadian mussel industry in a healthy and productive ecosystem.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Paul Simpson (Island Sea Farms Inc.)

PROJECT TEAM: Ron Francis, Linda Hiemstra (Island Sea Farms Inc.); Samantha Richman (U. Rhode Island); Erika Lok (Canadian Wildlife Service); Gregor Reid (DFO)

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DEVELOPMENT OF GENOMIC HEALTH ASSESSMENT TOOLS FOR MARINE MUSSELS (MYT-OMICS)

The BC coastline is under increasing pressure from competing coastal zone utilization and potential climate change impacts, highlighting the need for effective diagnostic tools of coastal ecosystem health and function. One of the major problems in assessing shellfish health is how to determine the organism's response to multiple stressing agents in the natural environment such as temperature, salinity, oxygen levels and diet as well as to anthropogenic effects such as xenobiotic pollution and aquaculture husbandry methods. Unexplained shellfish mortalities in four major BC aquaculture companies accounted for $6 million in lost sales in 2007 alone. It is likely that the complex interaction of these factors is responsible for the mass mortality events seen, although it is not known to what extent each factor contributes and what combinations result in fatalities.

Marine mussels (*Mytilus* spp.) are dominant members of coastal and estuarine communities and are established worldwide keystone bio-indicator species and aquaculture organisms. Within this project we will develop genomic information and tools for use in the study of *Mytilus* spp. We will use these tools to examine the stress responses of *Mytilus* spp. with the goal of understanding the causes of seasonal mortality. An understanding of the factors responsible for significant mortality events can be used by the shellfish industry to develop management practices to reduce their losses. In addition genomic information and tools developed within this program will be available for use by other research groups. This project is complementary to our Genome BC project funded under the Science Opportunities Fund program.

SEPT. 2009 – JUNE 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Taylor Shellfish Canada; Genome BC Science Opportunities Fund

PROJECT LEAD: Stewart.Johnson@dfo-mpo.gc.ca

PROJECT TEAM: Helen Gurney-Smith, Don Tillapaugh (VIU)

COLLABORATORS: Bill Taylor (Taylor Shellfish Canada)

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INCREASING VACUUM PACKAGING EFFICIENCIES IN BLUE MUSSEL PROCESSING

Allen's Fisheries Ltd. (AFL) in partnership with Badger Bay Mussel Farms Ltd. proposes to upgrade their vacuum packaging equipment for Blue Mussels. This specific processing equipment is currently being used for European mussels, *Mytilus galloprovincialis*; at Allen's the equipment will be used to process Blue Mussels, *Mytilus edulis*. Vacuum packaging of mussels is a way to deal with the peaks and valleys of production due to the natural inconsistencies in farm based supply.

This vacuum packaging equipment will be the first of its kind in North America. Unlike North American companies, European companies are further advanced; they spend more time and resources in research and development of processing equipment. Europe is focused on equipment efficiencies and reducing the amount of labour needed to complete a task. For instance, the debysser has a higher speed and is said to give a better product with less breakages than the North American equipment. This is an opportunity to adopt equipment from other markets to make the product competitive in international markets. Advancements in vacuum packaging equipment will lead to a better product line as a cheaper cost to the processing industry.

APR. 2011 – DEC. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Craig Allen (Allen's Fisheries Ltd.)

PROJECT TEAM: Craig Allen, Sean Allen (Allen's Fisheries Ltd.)

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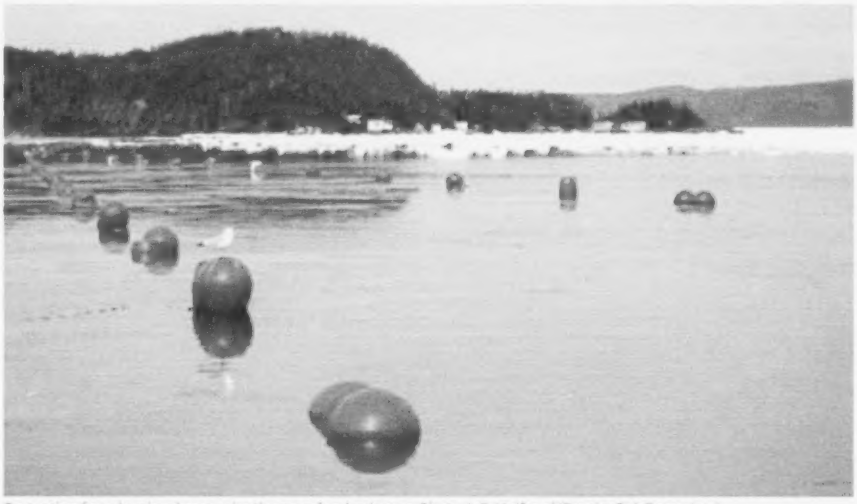
ARCTIC ICE BOOM INNOVATION FOR MUSSEL FARM PROTECTION



Protection from bay ice damage by the use of an ice boom. *Photo: L.C. Halfyard (Sunrise Fish Farms Inc.)*

New ice boom technology is being developed by Sunrise Fish Farms Inc., one of the Newfoundland pioneers for cultured Blue Mussel technology for our cold Arctic waters. To meet the demand for increased production, security of existing and new growout waters is necessary. Many sites on the northeast coast of NL are at risk during the winter/spring ice conditions. Existing ice boom technology helps to control most bay ice conditions, but has limitations when winds and currents allow ice to slice under the boom to enter the site, and potentially damage floats and mussel lines.

Partners in this project include North Atlantic Marine Services Inc. in its St. John's and Halifax fabricating facilities. Also, C-CORE, based at the Memorial University of Newfoundland, is providing engineering advice on local ice conditions, as well as potential stresses on the ice boom and shore mooring systems. North Atlantic Marine Services Inc. is leading the fabrication and breaking strength testing of the new ice boom system. The design includes a submerged skirt system that will allow bay ice to catch in the mesh, preventing the boom from lifting, and preventing ice slipping underneath as occurs for a typical surface boom. The boom will be in place before freeze-up in December 2012, allowing in-situ performance testing during the 2013 winter season.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP); National Research Council (NRC)

PROJECT LEAD: Laura C. Halfyard (Sunrise Fish Farms Inc.)

PROJECT TEAM: A. Job Halfyard, Trenton Johanson (Sunrise Fish Farms Inc.)

COLLABORATORS: North Atlantic Marine Services Inc.; C-CORE

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IMPROVEMENT OF QUALITY AND PRODUCTIVITY ASSOCIATED WITH LIVE BLUE MUSSEL INSPECTION THROUGH THE INSTALLATION OF AUTOMATED SORTING EQUIPMENT

Allen's Fisheries Ltd. (AFL) proposes to purchase and install an automatic sorting and defect removal system supplied by Best Sorting Systems Inc., Belgium, to improve the quality of live Blue Mussels processed at the plant and improve plant productivity. The technology does not exist in Canada and has not been used to sort mussels.

The goals/objectives of this project are to improve productivity and quality of finished mussel products and to reduce producing costs. AFL has completed preliminary investigation into available technology and have concluded the processing advantages of incorporating new automating sorting technology. The use of automatic sorting systems will provide improved finished product quality, increased productivity and volume. The system would provide inspection capacity up to 8,000 kg per hour or double the current production level. Manual inspection processes are labour intensive, not always effective and often monotonous. The manual inspector performance is significantly reduced as the shift progresses and is influenced by employee vision, process lighting and worker fatigue.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Fisheries Technology and New Opportunities Program (DFA-FTNOP); National Research Council (NRC)

PROJECT LEAD: Sean Allen (Allen's Fisheries Ltd.)

PROJECT TEAM: Richard Allen, Craig Allen (Allen's Fisheries); Bob Hardy (Hardy Fish Co. Ltd.)

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AN INVESTIGATION OF THE LIPID AND FATTY ACID COMPOSITION OF THE BLUE MUSSEL WITH REFERENCE TO PALATABILITY AND TASTE DURING CONDITIONS OF EXTENDED HOLDING

The Newfoundland mussel culture industry is poised to undergo a period of significant expansion in production and therefore the amount of harvested fresh product will increase. In many cases the product may be held at processing facilities awaiting transport. Unfortunately, storage of mussels over longer periods has been found to result in reduced meat yield, quality, and mortality. Recent work on a related project has indicated a significant loss in dry weight and condition index in mussels held for as little as one month during summer and fall. These types of changes in meat quality can be reflected in lipid, fatty acid, and glycogen content and hence taste and palatability. The current project will examine the variability in biochemical composition of Blue Mussels (*Mytilus edulis*) with a focus on lipid and fatty acid content under industrial standards for long-term holding and then, through the use of panel taste testing, determine if potential variations in lipid and glycogen content will affect product quality.

SEPT. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Norlantic Processors Ltd.

PROJECT LEAD: Harry Murray (DFO)

PROJECT TEAM: Lynn Hobbs, Sharon Kenny, Gehan Mabrouk (DFO)

COLLABORATORS: Terry Mills (Norlantic Processors Ltd.)

CONTACT: Harry.Murray@dfo-mpo.gc.ca

COMPARISON OF THE HEALTH AND CONDITION OF CULTURED MUSSELS FROM DEEP AND SHALLOW WATER SITES IN NEWFOUNDLAND WITH REFERENCE TO ENVIRONMENTAL CONDITIONS, CONDITION INDEX, PHYSIOLOGICAL STRESS AND LIPID BIOCHEMISTRY

The Newfoundland mussel culture industry is poised to undergo a period of significant expansion in production due to increased utilization of existing approved culture sites as well as the development of new sites. Mussels are typically cultured in sheltered near shore areas (river mouths, estuaries, harbours, and shallow bays); however, these sites can be negatively affected by land run-off, especially during times of significant precipitation, exposing mussels to land-based contaminants. Benthic deposition (i.e., mussel drop off, faecal material, and rejected particles known as pseudo-faeces) and increased pressure for lease space in these areas has raised concerns regarding the *ecological carrying capacity** and sustainability of coastal shallow water culture sites. Recent interest in the development of offshore deep water bivalve culture could potentially reduce many of the issues associated with near-shore sites. Deep water offshore sites show less benthic impacts by deposition, higher chlorophyll concentrations, and experience natural upwelling events which can bring additional nutrients and particles into the water column. Offshore sites offer a combination of a concentrated food source and potentially greater water quality which should support improved culture conditions and a corresponding decrease in animal stress, ultimately improving mussel condition and health. This project will characterize and compare seasonal changes in environmental conditions in offshore deep water and standard coastal shallow water mussel culture sites in Notre Dame Bay, Newfoundland. Researchers will investigate potential correlations with mussel condition, physiological stress indicators and lipid biochemistry to determine the environmental sustainability of each culture site.

**Ecological Carrying Capacity: is the highest stocking density that can be cultured without compromising other components of the ecosystem (for example: phytoplankton depletion)*

JULY 2012 – MAY 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Norlantic Processors Ltd.

PROJECT LEAD: Harry Murray (DFO)

PROJECT TEAM: Kim Hobbs, Sharon Kenny (DFO)

COLLABORATORS: Terry Mills (Norlantic Processors Ltd.)

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NEW AND INNOVATIVE EQUIPMENT FOR MUSSEL PROCESSING INDUSTRY

In 2010, planning began for a major retooling at PEI Mussel King concentrating on modernizing its facility and increasing its capacity for value added production. The project had many parts, but the most consideration was given to finding innovative equipment solutions to automate key processes.

Specifically, the project was for the purchase of a complete line of equipment for the automated vacuum-packaging of in-shell mussels. This equipment installed is the first of its kind in the Canadian mussel industry. Generically known as a horizontal-form-fill-seal (HFFS) line, such equipment is commonly used in many packaging applications. However, the special challenge of packing whole shell mussels required a fully-customized line with one-of-a-kind innovations. The installation of this equipment has been very successful, meeting and exceeding the proponents' expectations.

The greatest cost savings resulting from this project is in the direct labour column. Based on the same process steps pre- and post-project, Mussel King expects to realize a 75% saving. Film costs are higher, but these are offset with savings in labels. Mastering the mussel pouches at the time of production represents a yearly saving and less waste in product and packaging material.

Pressure to lower costs, a smaller and more sophisticated labour force, and the need for new production capabilities have all driven this innovative project.

APR. 2011 – MAR. 2012

FUNDED BY: Province of Prince Edward Island **CO-FUNDED BY:** DFO – Aquaculture Innovation and Market Access Program (AIMAP); Atlantic Canada Opportunities Agency (ACOA)

PROJECT LEAD: Esther Dockendorff (PEI Mussel King Inc.)

PROJECT TEAM: Scott Dockendorff (PEI Mussel King Inc.)

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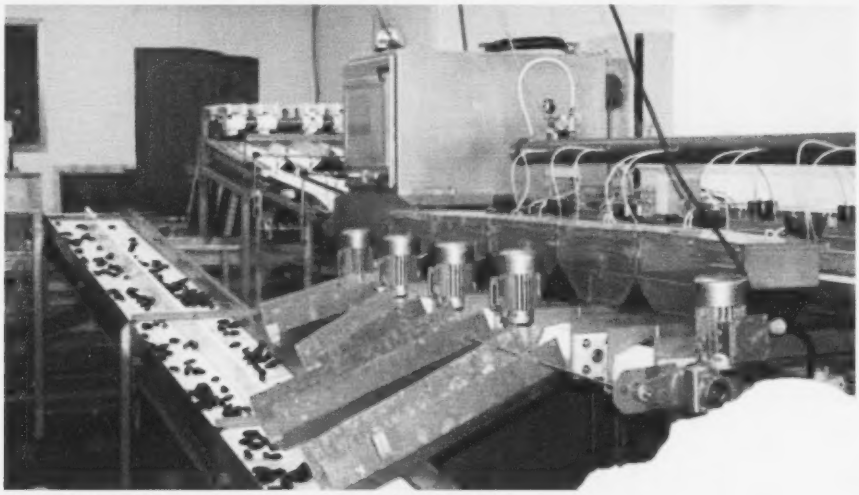
A PROJECT TO DEVELOP AND INTRODUCE AUTOMATED, DIGITAL IMAGING TECHNOLOGY TO THE GRADING PROCESS IN CANADIAN MUSSEL PLANTS



Blue Mussel imaging sorter. *Photo: Confederation Cove Mussels Co. Ltd.*

Confederation Cove Mussels Co. Ltd. developed a fully operational mussel grading system. This innovative grading system uses image acquisition and analysis using a specially designed software algorithm to grade mussels at a high speed. Mussels are fed over four grading belts and their images are acquired in real time to allow grading at a rate of 8 mussels per second per lane or 25-30 mussels per second per unit. Mussels are separated at high speed for such elements as size, shape, and meat content, while also identifying and removing any defective units.

Digital imaging technology is dependent on the object being in a consistent location and format to give a repeatable process. The greatest technical challenge was resolved in the application of the Auxiliary Handling Equipment. A great deal of energy was spent on designing mussel handling equipment that could effectively singulate and organize mussels in a consistent pattern at high speed.

This new automated grader will change the fundamentals of processing and deliver significant concrete and indirect benefits to the industry including lowering and controlling labour costs, improving both quality and food safety performance and making the whole grading process more consistent and predictable.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Atlantic Canada Opportunities Agency (ACOA); Province of Prince Edward Island

PROJECT LEAD: Len Currie (Confederation Cove Mussels Co. Ltd.)

PROJECT TEAM: Melanie Waite (Confederation Cove Mussels Co. Ltd.)

COLLABORATORS: Lizotte Consultants; Atlantic System Manufacturing

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HTTP://CONFEDERATIONCOVE.COM

EVALUATION OF BLUE MUSSEL PROCESSING PLANT HOLDING SYSTEMS IN PEI

As Blue Mussels become more of a commodity, processors are looking for new and improved holding systems and methods while maintaining high product quality. Current systems have shown limited holding mussel capacity (defined as the length of time live mussels can be held in wet storage). Better holding systems and/or practices would improve the industry's ability to compete in international markets. The goal will be to develop better holding methods by evaluating water quality in holding systems, assessing time of harvest impacts and thermal shock on shelf life, and conducting a preliminary evaluation of emersion/immersion cycles on mussel shelf life.

JUNE 2011 – MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** PEI Mussel King (1994) Inc.

PROJECT LEAD: Daniel Bourque (DFO)

PROJECT TEAM: Luc Comeau (DFO)

COLLABORATORS: Esther Dockendorf (PEI Mussel King (1994) Inc.)

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MUSSEL LARVAE PRODUCTION ENHANCEMENT BY RESTOCKING MUSSEL BEDS IN BASSIN DU HAVRE-AUBERT, MAGDALEN ISLANDS

Mussel production has been an important part of Magdalen Islands aquaculture industry for the previous thirty years. Natural mussel spat is facilitated via rope collectors set in the shallow Bassin du Havre-Aubert (BHA). This is the first crucial step in the mussel growing process on the Magdalen Islands. When grown sufficiently, juvenile mussels are socked (placed in plastic rope nets) and transferred to one of two mussel farm sites.

Since 2004, mussel growers have observed three years in which seed collection in BHA was very poor. Many reasons have been advanced in an attempt to explain this drastic decline of spat abundance. One of them focusses on mussel biomass and, through that, spat production. Mussel beds were inventoried between 2001 and 2009, and it was found that biomass had declined by 98 %. Decreased mussel biomass and wide distribution over BHA could explain observed spat declines and, therefore, mussel seed collection success.

Since 2009, Merinov-Centre des Îles has been involved in a new project on mussel bed restoration in BHA. Collectors were first installed at grower installations in the bay. The following summer, mussel seeds were removed from collectors and grown in socks for one year to contribute to the spawning effort. Finally, mussels were seeded on the bottom close to grower installations. Results from seed harvesting in the year following the first and the second restocking attempt have indicated significant success in BHA mussel restoration.

JUNE 2011 – MAR. 2014

FUNDED BY: MAPAQ

PROJECT LEAD: Carole Cyr (Merinov)

PROJECT TEAM: Carole Cyr, Lisandre G. Solomon, François Bourque (Merinov)

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TECHNICAL-ECONOMIC ASSESSMENT OF AN INTEGRATED MUSSEL POST-HARVEST PROCESS

Floating platform used for wet holding. *Photo: Jacques Dufresne (Les Moules de Gaspé Inc.)*

In shellfish culture, there are sometimes periods of faecal coliform contamination that exceed the standards set by the Canadian Shellfish Sanitation Program (CSSP). This obstacle limits structured annual aquaculture operational planning and effective commercialization. Moule de Gaspé Inc. must now handle all processing steps previously performed by a plant, from processing to marketing. The proponent intends to integrate the post-harvesting steps into one on-vessel operation and then transfer its batches of mussels in a wet holding system in a floating platform. A compact, innovative device (Kramer C700) will be used to perform post-harvest interventions in one step, which will limit handling and save space on-board the vessel, as well as time and money (i.e., elimination of the costs associated with transportation and with pumping process and treatment water). A secondary goal involves bringing the company's batches of mussels outside the contaminated area in a floating platform during closed times so that they can purify themselves naturally. A validation of the protocol will be done in consultation with CSSP members to determine the operational parameters for depuration in the natural environment.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Merinov

PROJECT LEAD: Jacques Dufresne (Les Moules de Gaspé Inc.)

PROJECT TEAM: Estelle Pedneault (Merinov)

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GENOMIC AND PHYSIOLOGICAL PROCESSES DURING THE LARVAL ONTOGENY OF THE BLUE MUSSEL: IMPACT OF EICOSANOID PRECURSORS

Found in many countries, *Mytilus edulis* is a bivalve cultivated directly in the natural environment. Therefore, survival, growth, breeding, and physiological performances depend on the environmental conditions at each aquaculture site.

The effect of two essential fatty acids (EAA and EPA) on the ontogenic pre- and post-larval development was studied by monitoring the building up of energy reserves, as well as the performances in terms of survival and larval growth. Furthermore, a functional genomic approach was then implemented using an Illumina HiSeq with high sequencing capacity. In this manner, 50,000 sequences were obtained for the various larval stages. Of these, 30,000 integrate functions in biological processes, as well as growth, localization, marking, apoptosis, stress response, and behavioural processes, etc. The results of the project show an increase in the lipidic reserves of the larvae at various ontogenic stages. The results also put into relief the fundamental role of these fatty acids in the building up of essential energy reserves, thereby providing for improved survival, immunocompetence and stress tolerance. The transcriptomics approach using DNA chips allowed for the identification of new transcripts which are potentially involved in some major biological functions, such as development and immunity, and also allowed for the global analysis of the ontogenic transcriptome of the Blue Mussel.

MAY 2010 – APR. 2013

FUNDED BY: Institut des Sciences de la Mer (ISMER); Institut universitaire européen de la mer (IUEM)

PROJECT TEAM: Sleiman Bassim, Réjean Tremblay (UQAR); Dario Moraga (U. Brest, France); Sophie Gauthier-Clerc (U. Montréal)

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THE EIDER SPIDER: DEVELOPMENT AND EXPERIMENTAL TESTING OF A NOVEL METHOD TO DETER SEA DUCK PREDATION ON MUSSEL FARMS

The cultivation of mussels is a growing industry worldwide, but predation by migrating sea ducks has been a challenge to mussel growers causing major financial losses. Ice coverage and the ducks' seasonal migration patterns limit their predation activity in most areas, but with the prospect of milder winters due to global warming, losses are expected to increase in the future. Mussel growers have adopted several techniques to *"scare"* ducks off mussel farms which include loud recordings, pyrotechnics, shooting, chemical deterrents, or chasing with boats; all of which have had limited success and are often subject to habituation. Protective socking material has also been tested; however, results have indicated that the socking material has unfavourable effects on the growth rate and production level. Since sea ducks are protected species, any deterrent method must ensure that it follows the framework of conservation laws and regulations. Therefore, there is a need for a deterrent mechanism that will not only be beneficial to the growers but would also be conservation-friendly. The Eider Spider sea duck deterrent system will be tested in field trials in Quebec and Nova-Scotia to provide the aquaculture industry with an innovative and efficient device to deter bird predation on mussel culture.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Société de développement de l'industrie Maricole (SODIM); Aquaculture Association of Nova-Scotia (AANS)

PROJECT LEAD: Priyum Koonjul (Valeo Management)

PROJECT TEAM: Estelle Pedneault (Merinov); André Mallet (Mallet Research Services Ltd.)

COLLABORATORS: Aquaculture Association of Nova Scotia (AANS)

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DEVELOPING AN INNOVATIVE TREATMENT SYSTEM FOR VASE TUNICATE FOULING ON CULTURED BLUE MUSSELS

Somers Island Blues Inc. of Murray River, PEI, will develop and assess a prototype system designed to mitigate the impact of Vase Tunicates on the applicant's mussel farms. The proposal is supported by a proof of concept that followed recommendations from the AIF Underwater Tunicate Treatment Trials Report. Air will be injected immediately behind the nozzle and a funnel (plastic cone – approx. 7" long) will be placed around the front of the nozzle to enable the water jet to travel from the tip of the nozzle to the treatment material at the end of the cone.

The sprayer will be mounted on a treatment platform custom designed for this project. All other equipment necessary for operating the system (e.g., motors and pumps) will be built into the frame of the platform and hydraulic, water, and air lines will be run under the deck to the sprayer assembly. This will reduce unnecessary clutter around the sprayer and make the system safer. In terms of efficiency, Somers Island Blues Inc. believes that a dedicated treatment system is the next step in managing the current tunicate infestation.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Province of Prince Edward Island

PROJECT LEAD: Chris Somers (Somers Island Blues Inc.)

COLLABORATORS: Province of Prince Edward Island

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IMPACT OF BIOTIC AND ABIOTIC FACTORS ON THE MECHANICAL PROPERTIES OF THE BYSSUS OF THE BLUE MUSSEL: A MARKETABLE BIOMATERIAL

This strategic research project focused on the production of the byssus of the Blue Mussel (*Mytilus edulis*). The project had two main objectives. The first objective was to identify the biotic and abiotic parameters responsible for the weakening of the byssus and the fall-off of the mussels during rearing, in order to improve the management of mussel production and promote sustainable aquaculture. The second objective was to explore the use of the byssus as an innovative and highly value-added product, notably by drawing on the unique mechanical properties of the byssal threads to develop biomaterials like nanofibres, biocompatibles, and biopolymers, etc. Our work demonstrated the impact of the rearing site (lagoon or open water), the reproductive effort (clutch size) and the metal content of the strands on the mechanical properties of the byssus. Furthermore, byssus production with a high level of stable carbon isotope (^{13}C) and infrared analyses enabled us to understand better the structure and composition of the byssus. Finally, this project led to the development of methods for the synthesis of biopolymers using byssus hydrolysate.

OCT. 2009 – NOV. 2012

FUNDED BY: NSERC; RAQ

PROJECT LEAD: Isabelle Marcotte (UQAR)

PROJECT TEAM: Bertrand Genard, Remy Hennebicq, Réjean Tremblay (ISMER); Frédéric Byette, Marc-Olivier Séguin Heine, Alexandre A. Arnold (UQAR), Christian Pellerin (UDEM); Bruno Myrand (Merinov)

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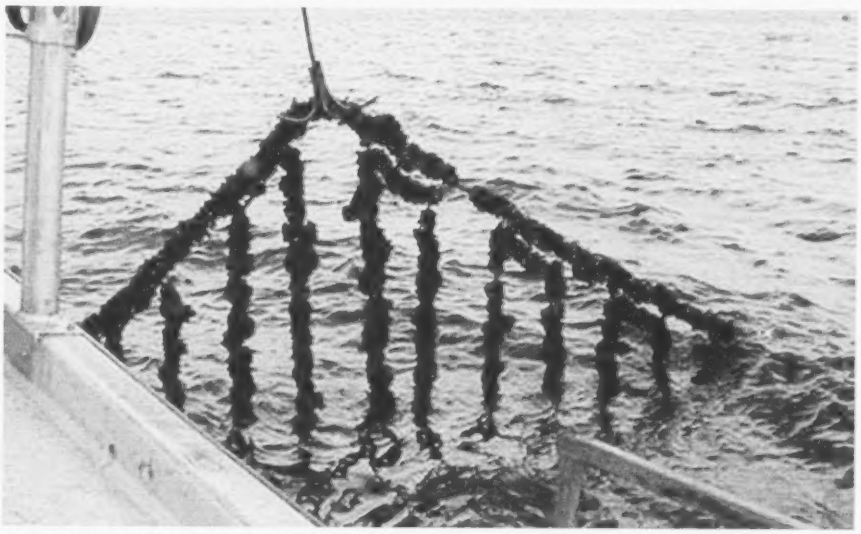

Mussel sock in the Gaspe. *Photo: Réjean Tremblay (ISMER)*

CULTURE DENSITY, BIOMASS-DENSITY RELATIONSHIP, AND SELF-THINNING IN MOLLUSCS

Harvesting mussels grown using a self-thinning technique. *Photo: Marcel Frechette (DFO)*

Aquaculture requires crucial decisions, regarding the stocking density of culture structures. Populations must be high enough to ensure profitability, but low enough to prevent overpopulation. An approach borrowed from forestry allows us to address this issue systematically. It involves studying the biomass-density relationship and self-thinning. This approach is currently little-used in aquaculture research and development. The purpose of this project is to provide examples of this theory for use in and development of mathematical models to facilitate its understanding and practical use. We previously worked with the Blue Mussel (*Mytilus* spp.). This work targets the Sea Scallop (*Placopecten magellanicus*) and the Surf Clam (*Spisula solidissima*). Our work suggests that self-thinning depends on, among other things, initial culture density. We have produced a mathematical model that can take this effect into consideration without multiplying the density levels studied. Also, our results indicate how mass mortality observed in scallop cultures in Asia was linked to self-thinning. In the next steps, we will examine the issue to determine whether clam dispersion can be better predicted through the biomass-density relationship.

1990 – MAR. 2012

FUNDED BY: DFO

PROJECT LEAD: Marcel Fréchette (DFO)

COLLABORATORS: José Urquiza, Gaétan Daigle, Dominique Maheux (U. Laval); Marianne Alunno-Bruscia (IFREMER, France)

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BIOENERGETICS AND MOLLUSC FOOD INGESTION

Bioenergetics helps us understand how environmental variables act on the growth of organisms in culture. It has applications in a variety of domains, such as support capacity, understanding environmental impacts of aquaculture, and forecasting climate change effects. Along with temperature, food ingestion is a crucial component of bioenergetics. The model species in our work is the Blue Mussel. However, our results are applicable to a wide variety of organisms. In a recent communication, we showed that the classic model describing food ingestion is inadequate. As a result, we developed a model based on a regulation by the animal's internal state. This model successfully describes effects such as, the spatial variability of growing conditions and physiological flexibility of feed in organisms. The next steps will focus on the analysis of an experiment testing our regulation model and, if necessary, improving it. We will also examine its performance in culture situations observed in France.

APR. 2010 – MAR. 2012

FUNDED BY: DFO

PROJECT LEAD: Marcel Fréchette (DFO)

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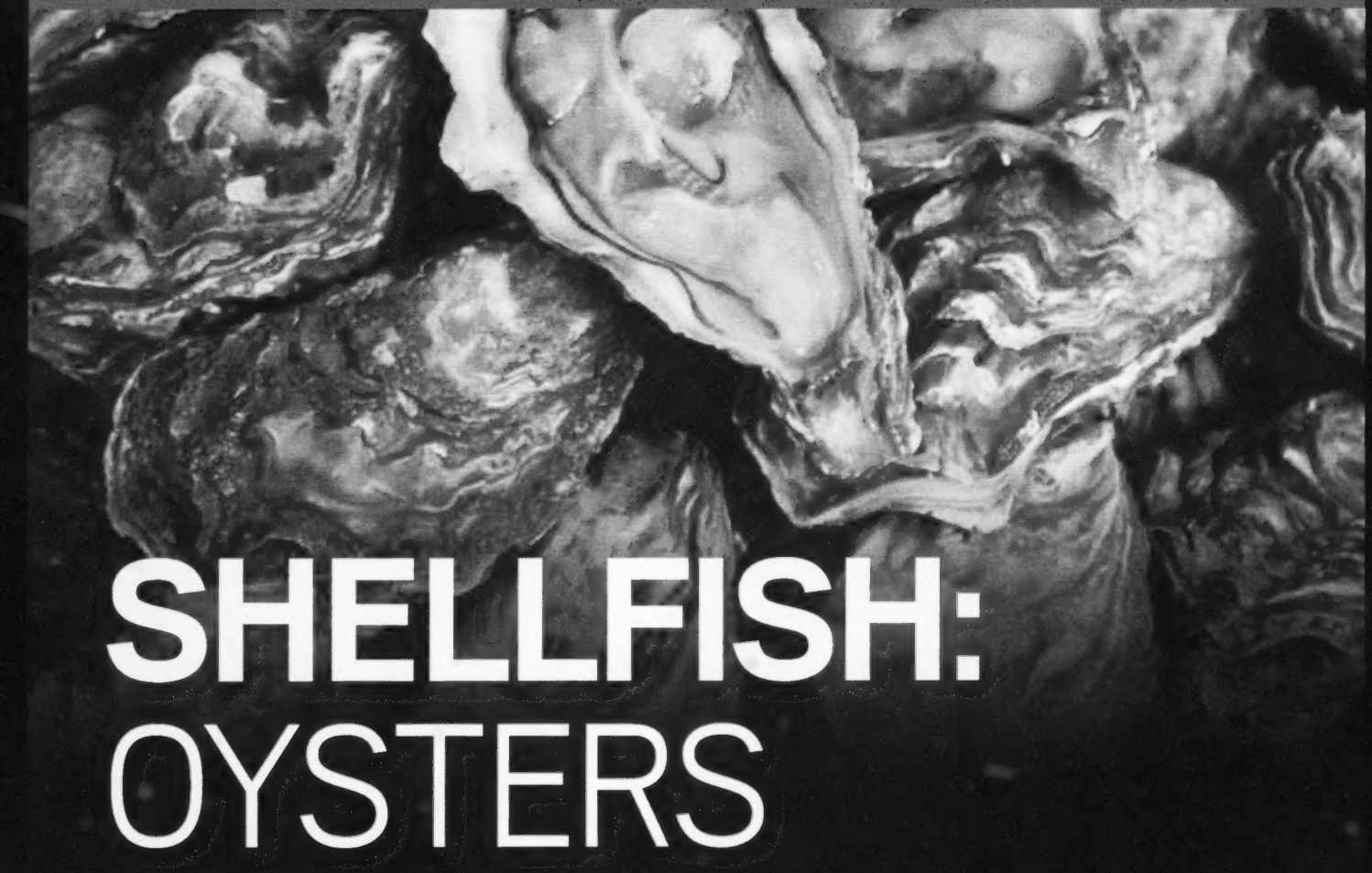
Blue Mussels. *Photo: Marcel Frechette (DFO)*



SHELLFISH: OYSTERS

An innovative approach for seed sorting in small farm operations

Innovations to produce single oyster seed in Pendrell Sound

Oyster production in hanging structures suspended from mussel long lines in Magdalen Islands

Introduction of commercial shell crushing technology to the BC oyster aquaculture industry

Development of a modified assay for use in temperate waters and its application through an assessment of stress tolerances among oyster stocks with varying levels of heterozygosity

A new method of growing bivalves in suspended culture

Optimization of the quality assurance process for the marketing of NB oysters

Baseline testing of tray rack inserts for a floating upweller nursery system

Development of an oyster grader targeting size (length) and unit specific to growers' operations

Development of tools to evaluate American Oyster shelf life

Comparison of an offshore and inshore site for oyster aquaculture

Influence of Eastern Oyster aquaculture on eelgrass populations and their recovery

Turning of OysterGro cages

Investigation into the decline of oyster production in the Hillsborough Bay area of PEI

Assessing seasonal variations in the physiological health of the Eastern Oyster

High density larval tanks for the American Oyster breeding program in New Brunswick

AN INNOVATIVE APPROACH FOR SEED SORTING IN SMALL FARM OPERATIONS

Mobile floating seed sorter and handling system. *Photo: Yves Perreault (Little Wing Oysters Ltd.)*

This project has developed a novel mobile floating seed sorter and handling system for oysters. It involved the purchase, assembly, and testing of seed handling equipment comprised of a seed screening machine, a specialized working raft, a system housing, solar power generation equipment, and other component equipment. Testing of this unique system resulted in a benchmarking study of productivity gains measured against past production costs and values.

The innovative system delivered a much greater increase to farm productivity than anticipated. A production increase of 75% was forecast; however, actual output increased by more than 300%.

This system is specifically designed to meet the needs of small farm operations. Mechanization of the seed grading stage clearly delivers a higher production rate with the same amount of labour. This enables farmers to invest more time into other production stages and to reduce overall costs per unit.

Little Wing Oysters Ltd. recommend other small firms consider similar investments. Growers across Canada can access the plans and final prototype system evaluation by contacting the project lead.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** French's Clams; NRC; VIU CSR

PROJECT LEAD: Yves Perreault (Little Wing Oysters Ltd.)

PROJECT TEAM: Edward Bereziak, Bob Paquin (Little Wing Oysters Ltd.)

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OYSTER PRODUCTION IN HANGING STRUCTURES SUSPENDED FROM MUSSEL LONG LINES IN MAGDALEN ISLANDS

The main objective of this project was to evaluate the bio-technico-economic potential of oyster production using hanging structures. Three rearing structures were compared: 1) Japanese lanterns; 2) oysters grown on vertical rope (glued); and 3) oysters grown on horizontal rope (rack). These structures were set on long lines at two mussel culture sites; House Harbour lagoon and Plaisance Bay offshore site. Oyster growth was greater for oysters cultured on vertical ropes in the lagoon. Oysters grew to about double their original size (from 30 to 67 mm in average) in one and half years. However, high percentages of mortality and oyster loss were noticed for this type of structure. These oyster mortalities/losses seem to be related with epibiont fouling on the oyster shell. A two-year project, which began in September 2011, will examine oyster structure cleaning techniques in an effort to solve the fouling problem.

APR. 2010 – DEC. 2013

FUNDED BY: Innovamer (MAPAQ); Canada Economic Development Agency (CED)

PROJECT LEAD: Lisandre G. Solomon (Merinov)

PROJECT TEAM: Lisandre G. Solomon, Carole Cyr (Merinov); Jean-François Laplante (UQAR/MAPAQ); Moules de culture des Iles; Moules du Large

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INNOVATIONS TO PRODUCE SINGLE OYSTER SEED IN PENDRELL SOUND

Aphrodite's Garden Oyster Co. will utilize unique methodologies for producing single oyster seed, in commercial quantities, locally, from the wild oyster spatfall in Pendrell Sound, offering lower costs to local growers, through innovation in the spat collector medium, initial nursery rearing stage, and sorting/processing in preparation for market. These innovations greatly reduce the carbon footprint of the unique seed production process by eliminating reliance on energy intensive hatchery operations. The work plan includes the use of re-manufactured materials and the natural spawning cycle of the oyster. Once set, most seed will normally mature in clumps of two or three oysters. Aphrodite's Garden Oyster Co. intervenes at this stage to produce single seed, which has a much higher value to growers.

The projects outcomes will be: 1) increasing productivity of area farms; 2) creating employment; and 3) protecting and enhancing a valuable asset on the BC Coast. These outcomes will comprise: 1) innovation in the seed collector substrate; 2) subsequent development of new equipment to deploy and retrieve these collectors; 3) design and construction of a seed stripper to remove the seed; and 4) development of a process to sort the single seed from clustered product.

This project will secure excellent value in an economical, natural product: viable, mature oyster seed for local growers, to re-access markets held by Pendrell seed prior to 1986. This is expedited while increasing environmental performance, using Pendrell's natural productivity to provide a sustainable alternative to non-local energy-intensive hatchery seed.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Ed Bereziak (Aphrodite's Garden Oyster Co.)

PROJECT TEAM: Lynn Paris, Bernard Hodges, John Svoboda; Dave Hameline (Aphrodite's Garden Oyster Co.); Yves Perrault (Little Wing Farms); Doug Bruce (Brock U.); Karen Burke Da Silva (Flinders U.)

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INTRODUCTION OF COMMERCIAL SHELL CRUSHING TECHNOLOGY TO THE BC OYSTER AQUACULTURE INDUSTRY

The purpose of this industry led benchmarking study was to locate a suitable technology to reduce oyster shell volume for the purpose of lowering material handling costs, and to enable value-added post processing opportunities in secondary markets. Two examples of secondary markets are animal feed supplements and water filtration.

Three different technologies were tested — a dual rotor shredder, a hammer mill, and a cage mill. Each machine had Pacific Oyster shell run through them under three different conditions — dry seasoned, wet seasoned, and green. Both the dual rotor shredder and the hammer mill performed very well, while the cage mill is not a viable option due to material feed issues. All of the machines produced much finer particle sizes than expected.

The introduction of a shell crushing technology to support British Columbia's shellfish sector is an opportunity to improve environmental performance and meet the needs of secondary markets. We believe that this technology will benefit the entire shellfish industry and Fanny Bay is in an excellent position to help introduce this solution and lead the way to more sustainable production.

APR. 2011 - MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Fanny Bay Oysters

PROJECT LEAD: Brian Yip (Taylor Shellfish Canada ULC)

PROJECT TEAM: Chris Barker (Taylor Shellfish); Alex Munro, Mandy Prowse (Fanny Bay Oysters)

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A NEW METHOD OF GROWING BIVALVES IN SUSPENDED CULTURE

Bivalve aquaculture currently utilizes two main farming practices: intertidal (bottom or beach) and deep-water (off-bottom, or suspended) culture. Suspended culture offers a number of advantages, but is often hindered by two issues: biofouling and shell deformities. The goal of our project is to assess the efficacy of expanded clay aggregate and lava rock as novel growth media for bivalves in suspended culture. Both media are lightweight, natural, pH neutral, chemically inert, affordable, and reusable. We anticipate these media to brush off biofouling, provide structural support, and act as a tumbling agent to prevent clumping and shell deformities. We focus on the two primary cultured bivalve species in British Columbia — Pacific Oyster (*Crassostrea gigas*) and Manila Clam (*Venerupis philippinarum*) — during nursery and grow-out. Our method has the potential to improve the efficiency of grow-out systems for these and other bivalve species.

JAN. 2011 - MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Mac's Oysters Ltd.

PROJECT LEAD: Anya Dunham (DFO)

PROJECT TEAM: Rob Marshall (Mac's Oysters Ltd.)

COLLABORATORS: Mac's Oysters Ltd.

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OPTIMIZATION OF THE QUALITY ASSURANCE PROCESS FOR THE MARKETING OF NB OYSTERS

La Maison Beausoleil (2010) Inc. of Neguac, NB, is supplied with oysters by over forty producers and can receive product from many different suppliers at the same time. This is the main reason why the company wants to develop an oyster processing line to automate receiving, washing and oyster storage in holding tanks. This automation will need to be integrated into the process of product traceability to reduce production costs, increase productivity, and maintain its position relative to standards and international competition. The project involves the mechanization and automation of the steps associated with oyster washing at receiving and loading of the product to storage holding tanks. Many of the components of automated production line need to be developed while others need to be adapted to enable component integration. A production line including a destacker and conveyor for full containers, empty container return, an inverter for full holding tanks, a washer, a unit charger, and a unit elevator will be developed and installed in the receiving area of the factory.

MAR. 2011 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP); IRAP; Province of New Brunswick

PROJECT LEAD: Amédée Savoie (La Maison Beausoleil Inc.)

PROJECT TEAM: Annie Thibodeau, Martial LeClerc (La Maison Beausoleil Inc.); Cube Automation; Vendée Concept

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DEVELOPMENT OF A MODIFIED ASSAY FOR USE IN TEMPERATE WATERS AND ITS APPLICATION THROUGH AN ASSESSMENT OF STRESS TOLERANCES AMONG OYSTER STOCKS WITH VARYING LEVELS OF HETEROZYGOSITY

There are many factors contributing to oyster losses, but for the most part, all these factors are related to stress. Stress can be caused by sub-optimal husbandry practices, environmental conditions, or the presence of pathogens. Rapid initial assessments of bivalve immune status can be measured using cellular biomarkers, in lieu of the more traditional long term indicators such as growth rates, mortality and condition index. The present investigation will verify the potential for error when using a cellular biomarker (neutral red retention assay) in oysters exposed to low water temperatures and attempt to improve this method in a controlled setting, so that it can be applied with confidence in the field. Fitness of oyster stock sources will be assessed by measuring level of genetic variation in a population (heterozygosity). Once levels have been measured, stock sources with the highest and lowest levels of heterozygosity will be assessed for their tolerance to stressful conditions.

MAY 2011 - MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Elsipogtog Fisheries

PROJECT LEAD: Carla Hicks (DFO)

PROJECT TEAM: Denise Méthé, Luc Comeau (DFO); Réjean Tremblay (UQAR)

COLLABORATORS: Blayne Peters (Elsipogtog Fisheries)

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BASELINE TESTING OF TRAY RACK INSERTS FOR A FLOATING UPWELLER NURSERY SYSTEM

BC shellfish farm. Photo: DFO

Mac's Oysters Ltd. will complete early commercialization and baseline testing of a new rack and tray insert system for the bins (silos) of a floating upweller nursery (FLUPSY). The system will be comprised of aluminum racks that hold seed trays and are suspended within the FLUPSY bins. These trays increase the culture surface area, allowing for a greater volume of seed than previously possible. This system reduces crowding and has tremendous potential to improve production through increased survival and potentially higher stocking densities.

Demand for the product continues to increase, yet the production from our FLUPSY is at a steady-state. Mortality rates are the major factor limiting overall production and are associated with periods of rapid growth which increase the volume of seed beyond the carrying capacity of the system. Increasing culture surface area through the implementation of the rack and tray system should reduce these rates significantly, and increase overall productivity. There are two systems that we will implement and test, a fully upwelling rack where the water is forced up through the bottom of all trays, and an upwelling/stacked raceway system where water is forced up through the bottom of the bin and then flows across the top of each tray.

The preliminary trials have shown favourable results with respect to growth and survival. For this reason Mac's Oysters believe that they are ready to move this system to commercial scale.

APR. 2012 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Rob Marshall (Mac's Oysters Ltd.)

PROJECT TEAM: Ron Willis, John Foster, Tom Haas, Janet Clark (Mac's Oysters Ltd.)

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DEVELOPMENT OF AN OYSTER GRADER TARGETING SIZE (LENGTH) AND UNIT SPECIFIC TO GROWERS' OPERATIONS

The project involves the development, adaptation and demonstration of a mechanized technology that will encourage site expansion, increase production of oysters, and allow for reduction in production costs thereby increasing profit margins for the growers. This project will take place in Bouctouche, NB, and involves a technology to grade and count oysters, the plant design layout preparations for the new and innovative technology, the acquisition, commissioning, and validation of the equipment, the development of an oyster washer, a profitability study, and a final report and communications.

MAR. 2012 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** National Research Council – IRAP; Province of New Brunswick

PROJECT LEAD: Donald Jaillet (Jaillet Aquaculture Inc.)

PROJECT TEAM: Mike McKenna (Atlantic System Manufacturing); Carl Brothers (Frontier Power Systems Inc.)

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DEVELOPMENT OF TOOLS TO EVALUATE AMERICAN OYSTER SHELF LIFE

Oysters continue to be popular seafood enjoyed by many. Because raw oysters in the shell are living organisms, they need to be stored under optimal conditions to avoid rapid loss of quality. Growers in Atlantic Canada have indicated that there are seasonal variations in oyster shelf life. Previous studies have mostly focused on traditional winter markets without considering how harvesting time and other husbandry practices associated with aquaculture may affect the oyster shelf life. This research will focus on the development of tools or techniques to: 1) determine shelf life of *C. virginica*; and 2) predict oyster shelf life prior to storage.

SEPT. 2011 - MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** La Maison BeauSoleil Inc.

PROJECT LEAD: Daniel Bourque (DFO)

PROJECT TEAM: Luc Comeau (DFO)

COLLABORATORS: Amédée Savoie (La Maison BeauSoleil Inc.)

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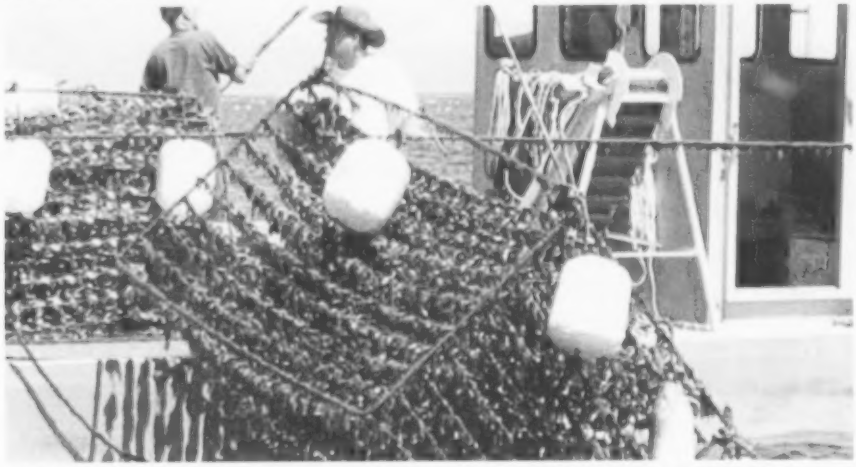
COMPARISON OF AN OFFSHORE AND INSHORE SITE FOR OYSTER AQUACULTURE



Modified Mediterranean French string technique—100 string unit developed by MP Aquaculture Inc. Photo: Kenny Aquaculture, MP Aquaculture Inc.

Comparison of an offshore and inshore site for oyster aquaculture using the French string technique in the Baie des Chaleurs, New Brunswick. The primary objective of this study is to assess the performance of oysters suspended on French strings in an exposed offshore environment compared to a sheltered inshore environment with respect to their ability to rapidly attain market size.

We will test whether oyster shell growth rates and reproductive rates are similar between offshore and inshore sites. Specific objectives of this research are: 1) to transfer the Mediterranean oyster culture technique (oysters on stings) to an offshore New Brunswick site; 2) to compare the growth, reproductive condition, survival, and market quality of oysters between an offshore and inshore site; 3) to compare fouling at an offshore and inshore site; and 4) to monitor the environmental parameters at an offshore site and an inshore site.

JULY 2009 – MAR. 2011

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Kenny Aquaculture

PROJECT LEAD: Monique Niles (DFO)

PROJECT TEAM: Luc Comeau, Leslie-Anne Davidson (DFO); Sylvio Doiron, (NBDAA)

COLLABORATORS: Thomas Kenny (Kenny Aquaculture); Marcel Poirier (MP Aquaculture Inc.)

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TURNING OF OYSTERGRO CAGES

Our project aims to develop a reliable approach to cage flipping (i.e., turning cages over) in order to control biofouling of the cages and the oysters they contain, with a view to improving net productivity and the economic viability of the oyster breeding industry.

The first objective is to determine the optimal frequency for flipping cages, the one which will eliminate the largest possible quantity of biofouling while reducing economic losses due to raising the cages out of the water and to breaking of the frill. This will be useful to the entire oyster industry in southeastern New Brunswick.

The second objective is to determine the shortest out-of-water time that will achieve a high degree of elimination of fouling organisms. The longer the period during which the oysters are out of the water, the greater their mortality. To reduce mortality as well as the growth loss that results from being out of the water, the optimal out-of-water time for eliminating biofouling needs to be determined, based on the size of the oysters.

SEPT. 2009 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Aquaculture Acadienne Ltée; King Aquaculture; Donald Jaillet

PROJECT LEAD: Angeline Leblanc

PROJECT TEAM: Marc Ouellette (DFO); Marie-Josée Maillet, Marcel Léger (NB Ministry of Agriculture and Aquaculture); Florent Garnerot, Chantal Gionet (CZRI); Erick Battaler (U. Moncton)

COLLABORATORS: Maurice Daigle (Aquaculture Acadienne Ltée); Armand King (King Aquaculture); Donald Jaillet

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INFLUENCE OF EASTERN OYSTER AQUACULTURE ON EELGRASS POPULATIONS AND THEIR RECOVERY

The aim of this project is to determine the extent and rate of recovery of eelgrass affected by two types of oyster culture methods (suspended bag and bottom table oyster culture) in order to develop best management practices for minimizing impacts on benthic habitat. The first objective is to monitor fine spatial and temporal scale recovery of eelgrass exposed to varying levels of benthic shading and organic enrichment from suspended bag culture structures with various oyster stocking densities. The second objective is to provide regional information on the influence of off bottom (table) culture of Eastern Oysters on eelgrass while determining the extent of recovery during fallowing periods for this culture method. There is a lack of reliable information about how to best place oyster tables in successive years in order to minimize cumulative impacts to benthic habitat (eelgrass). While data on the impacts to sea grass related to this culture method are available, very little research exists on the subsequent recovery of sea grass from such impacts. Furthermore, no known published results exist on impacts to and recovery of eelgrass loss and its subsequent performance during various recovery scenarios. This project will allow industry to develop best management practices to minimize initial impacts to benthic habitat as well as promote recovery in instances where impacts do occur.

MAY 2010 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** L'Étang Ruisseau Bar Ltée

PROJECT LEAD: Marie-Hélène Thériault (DFO)

PROJECT TEAM: Simon Courtenay, Marc Skinner (DFO)

COLLABORATORS: André Mallet, Claire Carver (L'Étang Ruisseau Bar Ltée)

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Eelgrass. Photo: S. Pereira (DFO)

INVESTIGATION INTO THE DECLINE OF OYSTER PRODUCTION IN THE HILLSBOROUGH BAY AREA OF PEI

The overall goal of this project is to investigate the decline in oyster production in natural and enhanced populations in the East, West, and North rivers of the Hillsborough Bay area.

The specific objectives of the project are to: 1) establish whether the oyster production problem involves recruitment, growth and mortality; 2) establish the spatial extent of the oyster production problem; 3) identify environmental and human activities that could cause a decline in production by degrading habitat given: human or animal disturbance to the beds, predation, sediment, water quality, and food availability; 4) produce a document that describes the extent of the oyster production issues in the Hillsborough Bay estuaries and the most likely cause(s) for the production problems based data analysis and biological plausibility; and 5) develop potential mitigation measures to improve the oyster fishery in these rivers (i.e., identifying areas for productive enhancement and fishing of wild oysters).

MAY 2012 - JULY 2013

FUNDED BY: PEI Aquaculture and Fisheries Research Initiative; PEI Department of Fisheries, Aquaculture and Rural Development **CO-FUNDED BY:** PEI Shellfish Association (PEI SA)

PROJECT LEAD: Sophie St-Hilaire (UPEI)

PROJECT TEAM: Jeff Davidson, Pedro Quijon, Erin Rees, Jonathan Hill (UPEI); Frank Hansen (PEI SA); Aaron Ramsay (PEI DFARD)

COLLABORATORS: PEI Shellfish Association; Department of Fisheries, Aquaculture, and Rural Development (DFARD)

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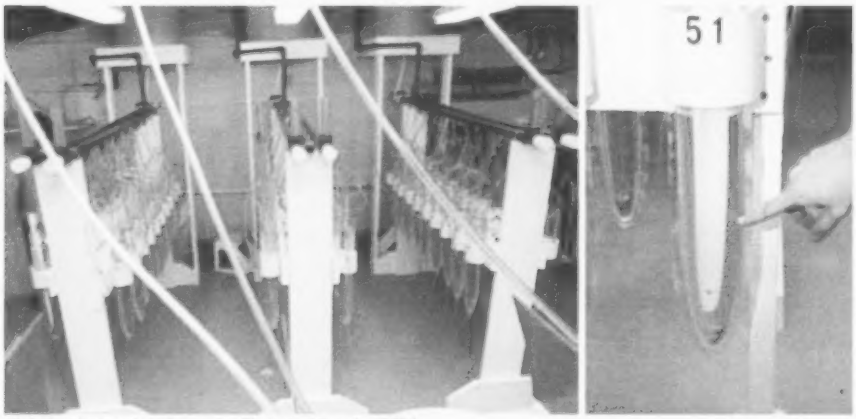
HIGH DENSITY LARVAL TANKS FOR THE AMERICAN OYSTER BREEDING PROGRAM IN NEW BRUNSWICK



High density larval rearing tanks. Photo: Joël Cormier (CZRI)

The Coastal Zones Research Institute (CZRI) acquired recently the Cawthron ultra density larval system from New Zealand to scale up its oyster breeding program. The system consists of 60 2.6-liter tanks. They will serve to increase significantly the number of families and larvae being produced every year, and foster the production of high performing spat. This acquisition enhances the selection breeding program to improve performance of the American Oyster (*Crassostrea virginica*) and initiated in 2005 by CZRI, thanks to the funding from Atlantic Canada Opportunities Agency and the New Brunswick Department of Agriculture, Aquaculture and Fisheries. Two cohorts of first generation (F1) were produced in 2005 and 2007 with promising results (10 to 21% faster growth in some families). In 2012 – 2013, the breeding program will move to the production of the second generation cohort (F2) and enter a new era for the benefit of oyster hatcheries and growers of New Brunswick.

MAR. 2012 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP); New Brunswick Department of Agriculture, Aquaculture and Fisheries; New Brunswick Professional Shellfish Growers Association

PROJECT LEAD: Chantal Gionet (CZRI)

PROJECT TEAM: André Dumas, Steven Mallet, Mélanie DeGrace, Josée Duguay, Rémy Haché, Yves Hébert, Isabelle Thériault, Marc-André Paulin (CZRI)

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ASSESSING SEASONAL VARIATIONS IN THE PHYSIOLOGICAL HEALTH OF THE EASTERN OYSTER

Cumulative mortality is a major issue within oyster culture. Under optimal conditions, a mortality of 5% per year is often observed, however, these numbers can vary considerably between lease sites. Producers compensate for these losses by increasing the number of oysters cultivated on their leases. However, increasing the number of oysters on each lease can greatly impact the environmental footprint of the site. Valuable resources within the ecosystem are lost (e.g., phytoplankton, nutrients, etc.) and on-site biodeposition is increased, without any return to the industry or consumers in terms of more oysters. This environmental impact becomes even greater in areas of reduced water exchange and areas of maximised carrying capacity. In New Brunswick, oyster mortalities appear to be closely related to environmental factors (e.g., temperature, salinity, etc.) and husbandry or rearing practices. The physiological health of the animal can determine how well it adapts and recovers from exposure to potential stressors. This study will assess variations in the health and condition of oysters (*Crassostrea virginica*) in New Brunswick in response to environmental changes to identify critical periods of physiological stress. This information will allow the development of management plans and best practices to help oyster producers avoid supplementary stressors, thus reducing mortalities and optimizing resource utilization. This could lead to more environmentally responsible operating practices for the oyster culture industry.

APR. 2012 - MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP); La Maison BeauSoleil Inc.

PROJECT LEAD: Daniel Bourque (DFO)

PROJECT TEAM: Denise Méthé (DFO)

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SHELLFISH: OTHER

Ecological interactions between benthic-ranched and wild California Sea Cucumbers

Nutritional requirements for sustainable crayfish aquaculture in British Columbia

Development of a nursery heating system to increase the production and availability of seed for the BC shellfish aquaculture industry

Are shellfish transfers a likely vector for aquatic invasive species movement from the west to the east coast of Vancouver Island?

Remodelling the scallop lantern net

Determination of optimal microalgal diets and feeding rations for larvae and seed of the Geoduck Clam

A pilot-scale wet-holding installation for increasing Bay Scallop sales

Geoduck grow-out using an innovative suspended culture technique

The ecological effects of clam harvesting by mechanical means in St Mary's Bay, NS

The influence of Manila Clam farming on biogeochemical fluxes

Optimization of hatchery-nursery practices for production of Sea Scallop spat in 10 m^3 tanks in Newport

Revision of the code of practice for the shellfish industry based on an evaluation system for standard operating procedures

Comparing culture gear and adapting off-shore giant scallop culture husbandry to Baie des Chaleur, NB

Cost reduction to produce American Lobster stage IV postlarvae for wild release

An assessment of the genetic and health status of the native Basket Cockle in BC for aquaculture operation facilitation

An innovative approach to nursery technology for the production of large Geoduck Clam seed: the missing link for Geoduck aquaculture in BC

Evaluation of risk mitigation measures for the potential introduction of invasive alga to facilitate bivalve spat transfer requests

Optimizing hatchery-based Sea Scallop settlement

The use of shells to increase recruitment and survival of Quahogs and Soft Shell Clams

Connectivity of Soft Shell Clam populations at various time and space scales

Adaptation of operations management software and "Le Mariculteur" mussel farming equipment

Effect of adaptation to temperature on the behaviour of stage IV larvae of the American Lobster

Use of diets enriched with stable isotopes (^{13}C) to optimize nutrition in the hatchery culture of bivalves

Optimization of scallop hatcheries by controlling the conditions of continuous stream production

ECOLOGICAL INTERACTIONS BETWEEN BENTHIC-RANCHED AND WILD CALIFORNIA SEA CUCUMBERS

In British Columbia, the California Sea Cucumber (*Parastichopus californicus*) supports a limited, but high-value fishery. Recently, increased market prices have generated a great deal of interest in farming sea cucumbers. Many of the proponents are interested in benthic ranching on the nutrient-rich seafloor beneath existing finfish and shellfish aquaculture sites. Research is required, however, to: 1) examine growth and survivorship of sea cucumbers in this nutrient-rich zone; 2) determine the success of maintaining cultured sea cucumbers within the boundaries of the farm site, with and without fencing; and 3) address the management concern that wild (non-seeded) sea cucumbers will immigrate onto the culture site and be harvested as cultured product. We are currently undertaking research to: 1) investigate the movements of adult sea cucumbers near aquaculture sites to determine potential interactions between benthic-ranched and wild animal; 2) examine the effects of stocking density and nutrient levels on the growth and survivorship of juvenile sea cucumbers both underneath and away from shellfish farms; and 3) examine if there is a reduction in organic loading underneath shellfish farms when sea cucumbers are present.

JULY 2012 – JULY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Klahoose Shellfish Limited Partnership; Kyuquot SEAfoods Ltd.; Viking Bay Ventures

PROJECT LEAD: Chris Pearce (DFO – PBS)

PROJECT TEAM: Laura Cowen, Paul van Dam-Bates (U. Victoria); Dan Curtis, Nick Duprey, Claudia Hand (DFO – PBS); Scott McKinley (UBC); Troy Bouchard (Viking Bay Ventures); Stephen Cross (Kyuquot SEAfoods Ltd., UVic); Chris Roddan (Klahoose First Nation)

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California Sea Cucumber (*Parastichopus californius*). Photo: Dominique Bureau (U. Guelph)

DEVELOPMENT OF A NURSERY HEATING SYSTEM TO INCREASE THE PRODUCTION AND AVAILABILITY OF SEED FOR THE BC SHELLFISH AQUACULTURE INDUSTRY

Securing a stable supply of seed is a major constraint to continued development of the shellfish industry. Although significant hatchery capacity can be found in BC, domestic hatcheries are generally unable to compete with the price and availability of US seed.

This AIMAP project will develop and demonstrate a novel nursery heating system specifically suited for colder climates such as Canada to increase production and availability of domestic shellfish seed supplies. The project will outfit current in-ground nursery facilities with a solar powered heater along with a custom pond cover to help retain heat. Current technologies including propane are not cost effective to heat such facilities over the winter months.

It is anticipated that this project will result in reducing the cost of heating seawater enough to increase the availability of seed at a competitive price earlier in the year. Growers will be able to extend the growing season, and compete domestically with seed imported from the US. Successful development of the nursery heating system will benefit not only the company through sales of seed and increased jobs but also the entire BC shellfish farming sector due to the industry-wide need for a stable supply of seed. In addition, this project will serve as a technology demonstration project for the Pacific shellfish industry.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Robert Saunders (Island Scallops Ltd.)

PROJECT TEAM: Yingyi Chen, Lisa Vernon, Barb Bunting (Island Scallops Ltd.)

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NUTRITIONAL REQUIREMENTS FOR SUSTAINABLE CRAYFISH AQUACULTURE IN BRITISH COLUMBIA

Signal Crayfish (*Pacifastacus leniusculus*) command a high price in both foreign and domestic markets. Although this species is cultured in foreign countries, there have been few attempts to raise Signal Crayfish within their native range which extends into southern British Columbia. We are currently undertaking research to establish culture techniques for this species. This work has included: 1) developing protocols for raising juvenile crayfish from the egg stage to 1 year; 2) investigating growth and survival of juvenile crayfish raised on a "typical" reference diet and diets where a large percentage of the protein source was from sustainable ingredients (duckweed or soybean meal); and 3) determining the digestibility and therefore the potential effectiveness of these feed ingredients for adult Signal Crayfish. Recent results have shown good growth and survival of juvenile crayfish up to 1 year of age when raised in vertical incubators designed for salmon culture. Juvenile crayfish showed similar growth and survival when raised on diets where either plant (duckweed or soybean meal) or animal based (fishmeal) ingredients were used as the primary protein source. These results suggest that Signal Crayfish are a good candidate for sustainable freshwater aquaculture in British Columbia and further work examining the digestive capabilities of this species is currently underway.

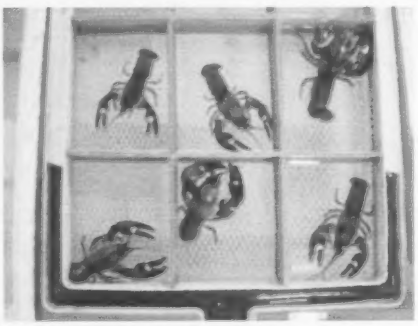
JULY 2010 – JULY 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Asturia Aquaculture Crayfish Consulting; Cordova Bay Golf Course

PROJECT LEAD: Chris Pearce (DFO)

PROJECT TEAM: Dan Curtis (DFO); Zeljko Djuric (Asturia Aquaculture Crayfish Consulting); David Groves (Broken Briar Enterprises Ltd.); Dean Piller (Cordova Bay Golf Course)

CONTACT: Chris.Pearce@dfo-mpo.gc.ca



Adult Signal Crayfish (*Pacifastacus leniusculus*) in a rearing tray. Photo: Anya Dunham (DFO)

ARE SHELLFISH TRANSFERS A LIKELY VECTOR FOR AQUATIC INVASIVE SPECIES MOVEMENT FROM THE WEST TO THE EAST COAST OF VANCOUVER ISLAND?

Wild and cultured Manila Clams (*Venerupis philippinarum*) and Pacific Oysters (*Crassostrea gigas*) harvested on the west coast of Vancouver Island (VI) must be sent to processing plants on the east coast of the island since presently there are no commercial shellfish processing plants located on the west coast of VI. In the past, processors have been permitted to "wet store" large quantities of harvested shellfish in the intertidal zone next to their processing plants or on aquaculture tenures, processing shellfish as time and markets allowed. There were concerns, however, that this practice could lead to the spread of the invasive European Green Crab (*Carcinus maenas*), that currently only occurs on the west coast of VI, and other non-indigenous aquatic invasive species (AIS) from the west to the east coast of VI.

The project's main objective is to assess whether shellfish as transferred by the shellfish industry and others can act as potential vectors for the spread of AIS, with particular focus on the European Green Crab, from the west to the east coast of VI. This project will quantify the potential risk of AIS spread from the west to east coast of VI associated with current shellfish transfer protocols by: 1) enumerating Green Crabs on Pacific Oysters, Manila Clams, and California Mussels from areas with Green Crab populations on the west coast of VI; 2) enumerating Green Crabs on west-coast VI shellfish products obtained from processors; and 3) building a database of the historical numbers and weight of shellfish transferred from the west coast of VI to east-coast VI processors. Currently, more research is needed in this area to assess the risk of this particular AIS vector.

JUNE 2011 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR) **CO-FUNDED BY:** Mac's Oysters Ltd.

PROJECT LEAD: Chris Pearce (DFO)

PROJECT TEAM: Lyanne Burgoyne, Dan Curtis, Graham Gillespie, Tom Therriault, Matt Thompson, Haley Matkin (DFO)

COLLABORATORS: Canadian Food Inspection Agency (CFIA); Mac's Oysters Ltd.

Adult European Green Crab (*Carcinus maenas*). *Photo: Miranda deVisser*

REMODELLING THE SCALLOP LANTERN NET

Redesigned scallop lantern net. *Photo: Barb Bunting (Island Scallops Ltd.)*

Further expansion of the BC scallop aquaculture industry is currently constrained by the challenge of acquiring suitable new farm tenures. Growth of the industry in part relies on innovations in farming technology and increases in production efficiency. This project attempted to improve the production efficiency of scallop farming during the ocean grow-out.

The standard technique used for the grow-out of scallops in BC is the cylindrical "lantern" net. This project remodeled the traditional lantern net to increase farm efficiency and productivity without increasing farm footprint. The team designed, built and tested a new, larger-diameter lantern net in anticipation of increased capacity.

Although the new net design did not prove to be suitable for the intended purpose of growing scallops to harvest size, it did show potential for culturing smaller scallops during the intermediate growth stage. The primary problem with the net designs was that, fully loaded with large scallops and fouled by epiphytes, the nets approached the maximum swing load rate for the booms on the work boats and were not very manageable.

Further trials will continue to assess growth rate and survival of scallops in the new lantern nets, but based on area alone the new design significantly increases the capacity of a farm by at least 50%. This is a useful step forward for scallop aquacuiture that increases farm productivity and decreases production cost.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Rob Saunders (Island Scallops Ltd.)

PROJECT TEAM: Bruce Evans, Lisa Vernon (Island Scallops Ltd.)

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DETERMINATION OF OPTIMAL MICROALGAL DIETS AND FEEDING RATIONS FOR LARVAE AND SEED OF THE GEODUCK CLAM

Juvenile Geoduck Clams (*Panopea generosa*). Photo: Chris Pearce (DFO)

The aquaculture industry of Geoduck Clam (*Panopea generosa*) in British Columbia has been constrained by the lack of a reliable seed supply, indicating inadequacy with the current hatchery production strategy. This project is aimed at identifying the optimal microalgal diets and specific nutritional requirements (especially fatty acids) for larvae/seed of Geoduck Clams and ascertaining the vital nutrients imparting high nutritional value to the diets. The research will also identify optimal microalgal rations for both larvae and seed, as well as examine the optimal rearing temperature and the possibility of replacement of live microalgae with commercially-available, spray-dried, microalgal diets for the seed. The results of this project will contribute significantly to the establishment and refinement of hatchery-rearing protocols of Geoduck larvae and seed, as well as to further expansion of the aquaculture industry of this species in BC.

AUG. 2010 – SEPT. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Klahoose Shellfish Limited Partnership

PROJECT LEAD: Chris Pearce (DFO)

PROJECT TEAM: Bianca Arney (UBC); Wenshan Liu (UBC/DFO); Ian Forster, Laurie Keddy (DFO); Chris Roddan (Klahoose First Nation)

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GEODUCK GROW-OUT USING AN INNOVATIVE SUSPENDED CULTURE TECHNIQUE

Geoduck aquaculture in British Columbia has been challenged by a lack of sea bottom tenures and a very long growing period to reach traditional marketable size (7 — 10 years to reach (~700 g). This AIMAP project addressed both issues by employing off-bottom suspended technology to produce a new "Baby Geoduck" product. The new product has been successfully test marketed and grows to market size in 18 to 24 months.

The primary goal of this project was to develop and test the innovative approach for culturing Geoduck. The longer-term object of the project was to introduce the "Baby Geoduck" (100 — 150 g) to market. Further development of the use of the suspended, off-bottom shellfish raft system continues at the Maplestar Seafood Ltd. farm at Nanoose Bay, BC.

The project results may be of interest to shellfish farmers with existing deepwater tenures in BC, particularly those employing raft culture of oysters and mussels. Farmers may be able to diversify production with the addition of a new, high value product.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Island Scallops Ltd.

PROJECT LEAD: Yu-Xin An (Maplestar Seafood Ltd.)

PROJECT TEAM: Francis Tran, Simon Yuan, Wenshan Liu (Maplestar Seafood Ltd.)

COLLABORATORS: Island Scallops Ltd.

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A PILOT-SCALE WET-HOLDING INSTALLATION FOR INCREASING BAY SCALLOP SALES

To date, three issues have prevented the significant expansion of Bay Scallop culture in the Maritimes: the short shelf-life which undermines attempts to reach distant markets; the inability to survive our cold winters; and, under-developed markets.

The objective of the project is to design and install a pilot-scale wet-holding system for Bay Scallops using recirculation technology and to better define the required environmental conditions to sustain high survival. Each 1200-L holding tank will be stocked with 4 stacks of 11 Dark Sea trays containing 20 lb of Bay Scallops per tray (880 lb or 400 kg/tank). Four air injection rings were installed in each tank at the base of each stack of trays to promote water circulation and ensure adequate oxygenation. Blocks of 10 holding tanks will be coupled to a re-circulating reservoir fitted with a coupling coil to maintain constant temperature in the system. The effect of temperature and tray stocking density on survival and product quality will be evaluated. The importance of using air-lifts to re-circulate the seawater in each of the holding tanks will be tested by comparing several configurations.

The project will take place at L'Étang Ruisseau Bar in Shippagan, NB. The results from this project will be immediately evident and useable by the aquaculture industry for the marketing of Bay Scallops.

MAR. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** National Research Council – IRAP; Province of New Brunswick

PROJECT LEAD: André Mallet (L'Étang Ruisseau Bar Ltée)

PROJECT TEAM: Claire Carver (Carver Marine Consulting); Claude-Henri Hébert (Losier, Larocque, Doiron, Hébert)

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THE ECOLOGICAL EFFECTS OF CLAM HARVESTING BY MECHANICAL MEANS IN ST MARY'S BAY, NS

Traditional hand harvesting is not considered to be a sustainable practice for providing seed for the development of clam aquaculture in Nova Scotia for various reasons, including social and economic factors. The clam aquaculture industry has experienced major challenges in the recruitment and retention of clam diggers, as well as a lack of interest from the younger employable population, resulting in an aging employee-base. Additionally, traditional hand harvesting is very labour-intensive and involves the use of a clam hake — with tines that measure about 15 cm in length, to dig up and turn over the sediment. A mechanical clam harvester has been used in Washington and British Columbia, and there is increased interest in utilizing a modified version of this harvester to compliment hand harvesting of Quahogs (*Mercenaria mercenaria*) in St Mary's Bay, Nova Scotia. This project will compare the ecological effect of traditional hand harvesting and a mechanical clam harvester. It will investigate the effects of each harvest technique on the ecological health and production of the area through the monitoring of the clam population, associated fauna and flora, and various physical and chemical parameters. Methods for reducing the ecological impact of harvesting, such as replanting pre-recruits on size-class plots and reducing repeated harvesting efforts, will also be investigated.

AUG. 2012 – MAY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Innovative Fisheries Products Inc.

PROJECT LEAD: Thomas Landry, Angeline Leblanc (DFO)

COLLABORATORS: Doug Bertram (Innovative Fisheries Products Inc.)

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THE INFLUENCE OF MANILA CLAM FARMING ON BIOGEOCHEMICAL FLUXES

This research examines how farmed Manila Clams (*Venerupis philippinarum*), the nets placed on beaches to protect them from predators, and the fouling organisms growing on these nets modify nutrient fluxes and benthic respiration in coastal British Columbia. We did an extensive manipulative experiment to separate these effects in Fanny Bay, Vancouver Island. Naturally occurring Manila Clams were removed from sixty 2.25 m^2 plots and the plots then manipulated to create 6 different treatments to evaluate the effect of 2 factors: *Clams* (two levels: with or without clams) and *Nets* (three levels: with cleaned nets, with fouled nets, and without nets). Plots were allowed to stabilize for one month before sampling was done. To evaluate biogeochemical fluxes, benthic respiration chambers were placed on the surface of each plot and water samples from within them taken over a period of a few hours at high tide. Water samples will be analyzed to evaluate nutrient [NH_4, NO_3, NO_2, PO_4, and $Si(OH)_4$] and oxygen levels and how they change over time. After incubations to determine fluxes, samples were taken to evaluate organic matter, meio- and macrobenthic infaunal communities from each plot. It is anticipated that the presence of clams, nets, and fouling will all increase fluxes and respiration. Results from this study will provide managers and the industry a better understanding of the influence of clam aquaculture on benthic respiration and nutrient fluxes in coastal zones and the factors that account for them.

SEPT. 2011 – DEC. 2013

FUNDED BY: Canadian Healthy Oceans Network (CHONe) **CO-FUNDED BY:** RAQ; DFO

PROJECT LEAD: Philippe Archambault (UQAR)

PROJECT MEMBERS: Marie-France Lavoie (ISMER); Christopher McKindsey, Christopher Pearce (DFO)

COLLABORATORS: Mac's Oysters Ltd.

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Fauna (Manila Clams) inhabiting beach plot beneath benthic respiration chamber used in the experiment. *Photo: Pauline Robert (UQAR)*

OPTIMIZATION OF HATCHERY-NURSERY PRACTICES FOR PRODUCTION OF SEA SCALLOP SPAT IN 10 M³ TANKS IN NEWPORT

The project involves producing Sea Scallop spat using an innovative hatchery-nursery method in 10 m^3 tanks. As this is the first Sea Scallop hatchery-nursery of this scale in Canada, the methods, procedures and farming systems used include several innovative elements (i.e., 10 m^3 tanks and an intermediate culturing area for attachment) that have never been tested for larval production. These innovative processes will improve the company's competitiveness, which is targeting an annual production of 25 million spat. By optimizing its practices in hatcheries and nurseries, the company will increase profitability by obtaining a better survival rate and an increase in high-quality larvae with a high concentration of lipids, thereby fostering optimal metamorphosis. Through the company's vertical-integrated production system, the implementation of reliable and reproducible protocols for spat production will increase environmental performance, encouraging the sustainability of the aquaculture industry. The expertise it develops through its participation in this project will enable the company to achieve its economic development potential and become a world leader in the production of scallop spat.

APR. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Ministère Revenu du Québec

PROJECT LEAD: Jean-Philippe Hébert (Fermes Marines du Québec Inc.)

PROJECT TEAM: Caroline Durant, Antoine Dumais-Roy, Marie-Hélène Desroches (Fermes Marines du Québec Inc.)

COLLABORATORS: Réjean Tremblay (UQAR/ISMER)

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10 cubic metre tanks. *Photo: Andre Drapeau (DFO)*

REVISION OF THE CODE OF PRACTICE FOR THE SHELLFISH INDUSTRY BASED ON AN EVALUATION SYSTEM FOR STANDARD OPERATING PROCEDURES

The project, sponsored by the New Brunswick Professional Shellfish Growers Association (NBPSGA), involves an update of the existing code of practice. This code currently exists in the form of Standard Operating Procedures and was recently produced for the eastern New Brunswick oyster industry. The new Best Practices in Oyster Farming Management tool will serve as reference for the mitigation measures that will serve to minimize or curb those risks as identified by shellfish growers during the assessment of the Standard Operating Procedures. The code will be a management tool to help all shellfish growers revise and adopt practices that will increase their competitiveness and environmental performance.

MAR. 2012 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation Market Access Program (AIMAP) **CO-FUNDED BY:** Province of New Brunswick

PROJECT LEAD: Micheline Després (New Brunswick Professional Shellfish Growers Association (NBPSGA))

PROJECT TEAM: Micheline Després (New Brunswick Professional Shellfish Growers Association (NBPSGA))

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COMPARING CULTURE GEAR AND ADAPTING OFF-SHORE GIANT SCALLOP CULTURE HUSBANDRY TO BAIE DES CHALEUR, NB

This study looks at the performance of Giant Scallops cultured in an exposed offshore environment using various husbandry approaches in order to minimize the negative impact of temperature fluctuations. Growth and reproductive condition of Giant Scallop cultured at an offshore site in Baie des Chaleurs: 1) in suspension using both lantern nets and in OysterGro™ cages; and 2) on the bottom using OysterGro™ cages, will be compared. The study will also assess fouling on the culture gear and monitor environmental parameters. An economic analysis of the feasibility of collecting Giant Scallop spat at the offshore site will be carried out.

MAY 2010 - MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP)

PROJECT LEAD: Leslie-Ann Davidson

PROJECT TEAM: Leslie-Anne Davidson, Luc Comeau, Rémi Sonier, Monique Niles, Rachel Nowlan (DFO); Sylvio Doiron (NB DAA)

COLLABORATORS: Thomas Kenny (Kenny Aquaculture)

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COST REDUCTION TO PRODUCE AMERICAN LOBSTER STAGE IV POSTLARVAE FOR WILD RELEASE

In 2002, the Maritime Fishermen Union teamed up with the Coastal Zones Research Institute (CZRI) to develop a simple and efficient technique for mass production of American Lobster (*Homarus americanus*) postlarvae stage IV for re-stocking initiatives. In 10 years, the CZRI went from a modest 1,500 to over 425,000 postlarvae in 2012. The CZRI continues its research and development activities in collaboration with its industrial partner, Homarus Inc., to improve the production techniques and develop specialized equipment for intensive rearing of lobster postlarvae. The primarily goal is to reduce production cost to allow the deployment of commercial hatcheries. The CZRI is now working on several aspects to achieve this goal: 1) the design of new tanks to transport more postlarvae over longer distance (higher density); 2) testing of a new type of frozen food; and 3) development of an automatic system to count larvae.

APR. 2002 - ONGOING

FUNDED BY: Homarus Inc.; Maritime Fishermen's Union

PROJECT LEAD: Rémy Haché (CZRI)

PROJECT TEAM: Yves Hébert, Caroline Roussel, Marc-André Paulin (CZRI)

COLLABORATORS: Martin Mallet (Homarus Inc.)

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AN ASSESSMENT OF THE GENETIC AND HEALTH STATUS OF THE NATIVE BASKET COCKLE IN BC FOR AQUACULTURE OPERATION FACILITATION

There is significant commercial interest in BC culture of Basket Cockle, *Clinocardium nuttallii*, due to its fast growth rate, cosmopolitan substrate choice, cold water adaptation and importance to First Nations diet. We assessed the genetic and health status of cockle samples from 14 widespread locations in all five BC Shellfish Zones to inform development of a regulatory regime for aquaculture.

The genetic analysis, conducted with ten microsatellite loci developed in the study, indicated most cockle samples belonged to a widespread, genetically homogenous group extending from northern BC to Vancouver Island. Genetically distinct cockles on Haida Gwaii may reflect isolation-by-distance resulting from restricted gene flow across Hecate Strait. Distinctive cockles sampled from Prince Rupert and Georgia Strait locations shared unusual allele frequencies at some loci, indicative of differentiation due to natural selection.

Cockles examined for parasites and disease using histology and light microscopy possessed none of the following bivalve pathogens or diseases of concern: *Marteiloides chungmuensis*, *Haplosporidium* spp., *Perkinsus* spp., *Marteilia* spp., *Bonamia* spp., *Mikrocytos mackini* or *Nocardiosis*. Other parasites and symbionts were not associated with pathology. However, fungal infections detected up to 15% of specimens from six locations were associated with significant pathology and host response.

OCT. 2010 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP)

PROJECT LEAD: Helen Gurney-Smith (VIU); Ruth Withler (DFO)

PROJECT TEAM: Stewart Johnson, Cathryn Abbott, Janine Supernault, Chris Pearce (DFO)

COLLABORATORS: We Wai Kai Nation (Shawn O'Connor); Centre for Shellfish Research (VIU); Aboriginal Aquaculture Association (Odd Grydeland)

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Basket Cockles. Photo: Helen Gurney-Smith (Centre for Shellfish Research, VIU)

AN INNOVATIVE APPROACH TO NURSERY TECHNOLOGY FOR THE PRODUCTION OF LARGE GEODUCK CLAM SEED: THE MISSING LINK FOR GEODUCK AQUACULTURE IN BC

The supply of Geoduck seed larger than the standard size of 8 – 10 mm shell length will significantly aid in the development of the Geoduck (*Panopea abrupta*) aquaculture industry in BC. Larger seed improves margins for tenure holders through higher survival of seed, improved seed performance, year round planting capabilities and up to a year reduction in required grow-out time.

To create this supply of seed, Nova Harvest Ltd. will apply innovative modifications to existing nursery technology for the efficient growth and overwintering of Geoduck Clam seed. On site, Nova Harvest will construct a land-based re-use nursery in parallel with outdoor algae culture tanks where local species of algae will be gown year round as feed. A second nursery to be tested is a floating ocean-based nursery fitted with hanging trays capable of holding substrate combined with a unique design that allows supplemental feeding of the entire floating nursery throughout the year using algae produced at the hatchery.

A successful nursery design will support the growth of the Geoduck aquaculture industry through increases seed supply, improved seed health and survival while lowering seed cost to the farmers. Farmers will be able to invest if greater numbers of seed with a higher survival rate improve the operational efficiency of the tenures.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: J.P. Hastey (Nova Harvest Ltd.)

PROJECT TEAM: Sean Williams (Nova Harvest Ltd.)

COLLABORATORS: Huu-ay-ahy First Nations

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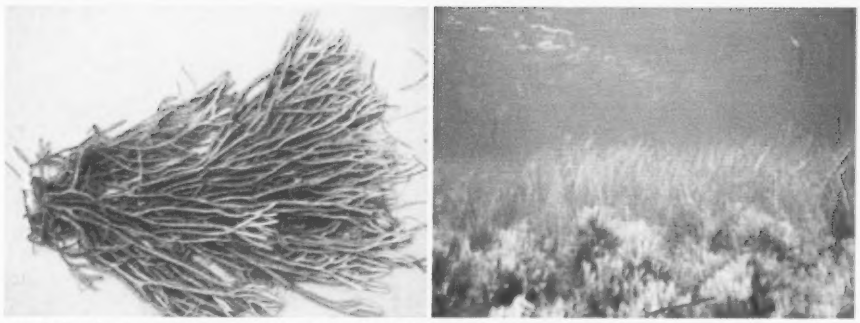
EVALUATION OF RISK MITIGATION MEASURES FOR THE POTENTIAL INTRODUCTION OF INVASIVE ALGA TO FACILITATE BIVALVE SPAT TRANSFER REQUESTS



LEFT: *Codium fragile* ssp. *fragile* growing on a mussel in Iles de la Madeleine. RIGHT: *Codium fragile* ssp. *fragile* growing in an eelgrass (*Zostera marina*) meadow in Iles de la Madeleine. *All Photos: C. McKindsey (DFO)*

The mussel farming industry in eastern Canada is largely based on the collection of spat in areas suitable for the settlement of larvae and transfer to growing sites until the mussels attain a harvestable size. In eastern Quebec (Gaspé region), this was typically done on a small scale (a few kilometres). In recent years, however, there have been several failures in collecting spat in the Gaspé Peninsula, forcing a number of mussel farmers to apply for transfers from a site on the south shore or Chaleurs Bay, near Miscou, NB. However, this area is known to be infested by the invasive green alga *Codium fragile* ssp. *fragile*. As a result, spat transfers cannot be authorized by the Introductions and Transfer Committee because this invasive alga, which affects shellfish growers' production, has not yet been observed in the Gaspé Peninsula. This potential loss of production is a major concern for the industry at this time. The project assesses the effectiveness of various treatments at different stages in the *Codium* life cycle likely to be associated with mussel spat with an emphasis on maximizing spat survival. The results would ensure that the risk of transferring *Codium* with spat is minimized. The study could also potentially result in new ways of treating other aquatic invasive species (AIS) while prioritizing treatments already known to be effective against other invaders in the Maritimes. The effectiveness of these procedures is also being evaluated on Sea Scallops (*Placopecten magellanicus*) and Eastern Oysters (*Crassostrea virginica*), species also targeted by transfers between the Magdalen Islands and the Acadian Peninsula and the Gaspé Peninsula. *Codium* was recently found in the Havre-aux-Maisons Lagoon on the Magdalen Islands and this limits transfers from this area, as it does from the Acadian Peninsula.

DEC. 2010 – DEC. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Société de développement de l'industrie maricole (SODIM)

PROJECT LEAD: Chris McKindsey (DFO)

PROJECT TEAM: Lysandre Landry, Nathalie Simard, Matthieu Huot (DFO)

COLLABORATORS: Léon Lantaigne (NB); Jason Simpson (PE)

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THE USE OF SHELLS TO INCREASE RECRUITMENT AND SURVIVAL OF QUAHOGS AND SOFT SHELL CLAMS

Successful recruitment of juveniles is an essential part of a shellfish aquaculture operation. This study will help us understand the recruitment process for Quahogs and Soft Shell Clams and how to improve it. The project will experiment with adding shells to sediment to see if this will change chemical parameters of the sediment, thereby increasing the recruitment and survival of juvenile clams, and possibly the growth of older clams. A secondary objective is to look at recruitment and growth data in relation to the site's physical attributes. Characteristics such as current velocity and erosion rates may explain a significant portion of the availability in recruitment of seed stock and growth. Identifying such explanatory factors would be helpful in the selection of aquaculture sites.

AUG. 2010 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Innovative Fisheries Products Inc.

PROJECT LEAD: Angeline Leblanc (DFO)

COLLABORATORS: Doug Bertram (Innovative Fisheries Products Inc.)

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OPTIMIZING HATCHERY-BASED SEA SCALLOP SETTLEMENT

During the life cycle of bivalves, the pelagic larval stages end with progression to benthic life via settlement and metamorphosis. Settlement is a significant limiting factor in the success of pectinid hatcheries. Although in some larval cultures, settlement success rates can reach up to 80% in good conditions, larval settlement and metamorphosis success rarely exceed 25 to 30%. Metamorphosis in bivalves is accompanied by the loss of their larval food collection system (velum) and the development of gills. This period is critical given larvae's limited ability to feed while undergoing metamorphosis. For metamorphosis to be successful, this change must be completed rapidly. Competent larvae will settle and undergo metamorphosis under the influence of various chemical, physical and biological signals that are still unknown for Sea Scallops. A project funded by the Government of Norway was undertaken in 2007 to identify signals that help to increase settlement and metamorphosis success in *Pecten maximus*. The results show the differences in the length of the settlement process, which can vary from one to four weeks depending on the size of the competent larvae. Shorter settlement duration favours faster growth of juveniles and represents an economic benefit for commercial hatcheries. The primary objective of this project is to increase settlement/metamorphosis success while reducing the time required for completing it. The ultimate objective is to establish a settlement rate of over 60%. To meet these objectives, the following combinations will be tested: Effect of size before transfer in the settlement system, effect of velocity and hydrodynamic conditions in settlement units, and interaction between size and hydrodynamics.

JUNE 2010 – MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Aquaculture Gaspesie Inc.; SODIM

PROJECT LEAD: Jean-Marie Sévigny (DFO), Réjean Tremblay (UQAR)

PROJECT TEAM: Nathalie LeFrançois, Pierre Blier, France Dufresne, Francis Dupuis (UQAR)

COLLABORATOR: Thorolf Magnesen (U.Bergen)

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CONNECTIVITY OF SOFT SHELL CLAM POPULATIONS AT VARIOUS TIME AND SPACE SCALES

Sampling of Soft Shell Clams at Port Mouton, NS. Photo: Philippe Gallpeau

The Soft Shell Clam (*Mya arenaria*) is a benthic bivalve mollusc whose global natural distribution presents significant potential for aquaculture. In the laboratory, we developed a series of eight microsatellite markers. These were highly polymorphic and adapted to the species in order to study the genetic structure of the populations at the scale of their distribution. The results revealed the existence of six genetically distinct groups corresponding to: 1) the northern Gulf of St. Lawrence; 2) the southern Gulf of St. Lawrence; 3) the Magdalen Islands; 4) lower Atlantic Canada; 5) the U.S. coasts; and 6) Northern Europe. Genetic differentiation seems primarily due to isolation by distance at the southern range of the distribution. At the northern range, genetic differentiation seems largely due to isolation by distance, barriers to dispersal, and selection processes. The latitudinal gradient of genetic diversity is indicative of postglacial species expansion northward. We also used the microsatellite markers to check whether we could follow the larval cohorts during a complete spawning season, from birth to spatfall, in Bouctouche Bay, NB. The results showed the presence of closely related larval cohorts and larval retention. The results will allow for improved stocking program planning in the context of aquaculture activities by maintaining the genetic integrity of natural stocks.

SEPT. 2008 – APR. 2013

FUNDED BY: NSERC **CO-FUNDED BY:** RAQ

PROJECT LEAD: Philippe St-Onge (UQAR)

PROJECT TEAM: Réjean Tremblay, Jean-Marie Sévigny (UQAR)

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ADAPTATION OF OPERATIONS MANAGEMENT SOFTWARE AND "LE MARICULTEUR" MUSSEL FARMING EQUIPMENT

Quebec mussel farmers currently use software known as "Le Mariculteur," property of SODIM, to manage their mariculture equipment and their on-site stocks. This software is a tool that enables easy management of production (by site and by line), infrastructure, and workforce (by activity). It also makes it possible to view a graphic representation of mussel farming sites, capture all the database information at once, and generate reports that facilitate management. The current project was implemented with the aim of adapting the software to the process and methods involved in scallop farming. Several aquaculture practices and equipment can be used for scallop production; therefore, these steps must be standardized as part of the software's programming. The software's integrated features will simplify scallop farmers' management tasks. It should be noted that this tool is user-friendly — it is suitable for use by operators who are not computer-savvy and will work on personal computers running Windows or Macintosh operating systems.

APR. 2011 – DEC. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Société de développement de l'industrie maricole (SODIM)

PROJECT LEAD: Sylvain Lafrance (Société de développement de l'industrie maricole (SODIM))

PROJECT TEAM: Nathalie Méthot, Jonathan Ranger (Gascode Inc.); Mélanie Bourgeois (Culti-mer Inc.); Stéphane Morissette (GRT Aquatechnologie Ltée.)

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HTTP://WWW.SODIM.ORG/

EFFECT OF ADAPTATION TO TEMPERATURE ON THE BEHAVIOUR OF STAGE IV LARVAE OF THE AMERICAN LOBSTER

It is now well known that water temperature strongly influences the behaviour of the American Lobster (*Homarus americanus*). Moreover, there seems to be a correlation between acclimation to a given temperature, the stock of origin, and the behavioural responses of the species. Although several studies exist, few have looked into the behavioural responses of stage IV larvae with regard to thermal gradients based on the incubation temperature and the originating stock.

To characterize these behavioural responses, an experiment will be conducted in the summer of 2013. Several berried females from two different stocks will be captured in the southern and northern parts of the Gulf. For each of these two source stocks, two sets of larvae will be incubated at temperatures of 12 °C and 20 °C for the duration of the larval development. At stage IV, the larvae will be exposed to a homogeneous water column (i.e., 20 °C and 12 °C) or a stratified water column (i.e., 20 °C at the surface and 12 °C at the bottom). These experiments will also take into account the type of sediment in the selected substrate.

JULY 2012 – JULY 2014

FUNDED BY: NSERC Canadian Capture Fisheries Research Network (CCFRN); NSERC

PROJECT LEAD: Leo Barret (UQAR)

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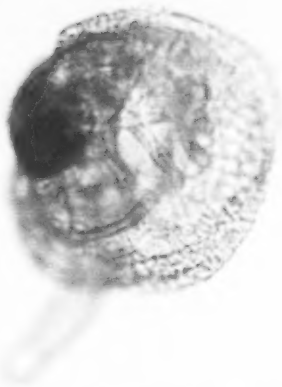
USE OF DIETS ENRICHED WITH STABLE ISOTOPES (^{13}C) TO OPTIMIZE NUTRITION IN THE HATCHERY CULTURE OF BIVALVES



Juvenile post-larval Sea Scallop, *Placopecten magellanicus*. *Photo: Réjean Tremblay (UQAR)*

The composition of bivalve larvae nutrition is based on empirical data that vary greatly from one hatchery to another in terms of microalgae species and quantity of feed. In this project, a microalgae-based diet enriched with ^{13}C is used to accurately monitor the levels of ingestion, absorption and incorporation of amino acids, fatty acids, and carbohydrates throughout the larval development of various bivalve species (*Placopecten megallanicus*, *Mytilus edulis*, and *Crassostrea virginica*). This study is based on several microalgae species with different biochemical profiles, which will accurately establish larvae amino acid, fatty acid, and carbohydrate requirements during their development. This information will be used to establish an optimal diet that will meet the nutritional needs of larvae, while preventing the rejection of organic matter inherent to overfeeding or improper ingestion or assimilation of food in rearing tanks. The project will therefore provide hatcheries with specific information for optimizing their production of microalgae for feeding larvae, while preventing the accumulation of organic matter, thereby reducing the risk of bacterial growth in tanks.

MAY 2012 – APR. 2014

FUNDED BY: NSERC; Fonds de développement académique du réseau des Universités du Québec (FODAR) **CO-FUNDED BY:** RAQ

PROJECT LEADS: Bertrand Genard, Marine Holbach, Réjean Tremblay (UQAR)

PROJECT TEAM: Nathalie LeFrançois, Pierre Blier, France Dufresne, Francis Dupuis (UQAR)

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OPTIMIZATION OF SCALLOP HATCHERIES BY CONTROLLING THE CONDITIONS OF CONTINUOUS STREAM PRODUCTION

For several years now, flow-through bivalve production techniques have been in development, notably in France for the oyster *Crassostrea gigas*, and more recently, the *Ostrea edulis* species. This new approach has clearly demonstrated that it is now possible to achieve substantial savings in terms of labour and make it easier to ensure the microbiological stability of aquaculture water, thereby limiting the development of opportunistic pathogens. Furthermore, this technique allows for the optimal and continuous inflow of microalgae, which would make it possible to set up very high-density hatcheries. This is the context in which the flow-through system was adapted to Pectinidae species. The larvae of this Pectinidae are known to be sensitive to bacteria in their rearing environment. Such bacteria are mostly to blame for the massive mortality rates observed both in flow-through systems and stagnant water systems. The objectives of this study are to: 1) limit the bacterial load of larvae in the early stages and select the most effective prophylactic measure to counter it; and 2) understand how the parameters of the culture chambers influence the physiology of larvae, in order to optimize larval yield.

JAN. 2010 – JAN. 2014

FUNDED BY: Ministère du Développement économique, de l'Innovation et de l'Exportation (MDEIE); Programme de soutien à des initiatives internationales de recherche et d'innovation (PSIIRI); Programme Européen Reproseed; RAQ

PROJECT LEAD: Marine Holbacg (ISMER – IFREMER)

PROJECT TEAM: Réjean Tremblay (ISMER / UQAR); René Robert, Pierre Boudry (IFREMER)

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Experimental flow-through system used at IFREMER. *Photo: Marine Holbacg (IFREMER)*

MISCELLANEOUS

Isolation, culture, and genomic analysis of harmful algal species affecting aquaculture on the west coast of Canada and analysis of the Harmful Algae Monitoring Program historical database

Aboriginal principles for sustainable aquaculture program phase 3: branding and marketing

Integrating red macroalgae into land-based marine finfish aquaculture

Brown Alga culture trials on the Gaspé Peninsula and the Magdalen Islands, Québec: pre-industrial scale-up in open-water and semi-enclosed environments of mussel farms

Assessment of the European Green Crab as a fishmeal replacement for salmonid aquaculture diets

Development of health products derived from Atlantic Canada bio-[illegible]ritional analysis of feeds cont[illegible]iched oil for Atlantic Salmon aquacultu[illegible]

Early warning and mitigation of the impact of invasive colonial ascidian tunicates

Canadian-Aquaculture-Styrofoam®-Encasement (CASE)

Assessment of a new natural ingredient for growth and pigmentation in Atlantic Salmon flesh

Identifying critical ecological thresholds for tunicate infestation on mussel farms

Aquaculture technology implementation

Research & development coordinator training in environmental management systems to assist aquaculture industry certification

Net drying innovation in aquaculture servicing

Development of a comprehensive fish waste utilization system that produces two products: nutraceutical fish oil and organic fish soil amendment

BC Environmental Management Code of Practice

Impacts of shellfish aquaculture on marine vegetation

The historical and social dimensions of salmon aquaculture science

Supporting and advancing key Canadian aquaculture standards and certification initiatives

Developing Camelina as the next Canadian oilseed

FishProbio: a sustainable and effective alternative strategy for preventing major opportunistic infections in salmonids

Development of a biodiesel production process from microalgae using cheese whey permeate

Novel antifouling technologies

Anaerobic digestion of fish offal and sawdust

Development of feed for culturing lobster larvae for seeding in a natural environment

Assessing the bioavailability of methionine and lysine from different sources

Physiology of triploid fish

A meta-analysis of essential amino acid requirements in fish

Protective barrier to counter Sea Otter predation

Photo: Paul Merlin (CanAqua Seafoods Ltd.)

ISOLATION, CULTURE, AND GENOMIC ANALYSIS OF HARMFUL ALGAL SPECIES AFFECTING AQUACULTURE ON THE WEST COAST OF CANADA AND ANALYSIS OF THE HARMFUL ALGAE MONITORING PROGRAM HISTORICAL DATABASE

HABs (Harmful Algal Blooms) are responsible for considerable economic losses due to cultured finfish/shellfish mortalities and toxic HABs in shellfish can threaten human health. With the support of the British Columbia (BC) salmon aquaculture industry, the Harmful Algae Monitoring Program (HAMP) was established in 1999 to address the devastating effect of harmful algae on farmed fish. Through systematic microscopic surveillance of water samples, HAMP has provided salmon aquaculture companies with monitoring data and early warning of HABs at farm sites. However, more research is needed to improve the knowledge of HABs as well as the ability to predict future blooms based on analysis of historical data. Researchers need to identify certain HAB species, cultivate these species for study, and analyze previous HAMP data on harmful algae to document potential trends. The first goal of this project is to isolate and culture microalgal species that are known to be harmful to cultured fish and shellfish in BC. These cultures will be used for detailed identification of species, preliminary studies of physical variations for each select species, development of species-specific quantitative polymerase chain reaction (PCR) assays, and creation of an image gallery and database of local harmful algae. These tools will be used to improve existing training and surveillance strategies. The second goal of this project is to carry out genomic analyses on shellfish gill tissues to determine genomic and biological responses to HABs and to link these responses with particular algal species. Finally, a retrospective analysis of 13 years of data from HAMP will be undertaken. This will significantly improve knowledge on spatial and temporal trends of local harmful alga blooms and will contribute to improving existing HAB surveillance and mitigation strategies.

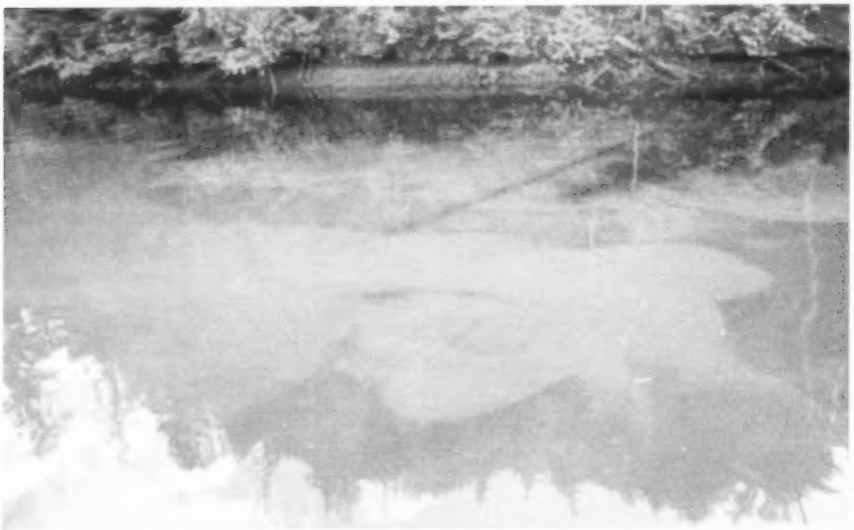
JULY 2012 - JULY 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Creative Salmon Company Ltd.; Grieg Seafood BC Ltd.; Mainstream Canada; Marine Harvest Canada Inc.; Cleanwater Shellfish Ltd.; Island Scallops Ltd.; Little Wing Oysters Ltd.; Mac's Oysters Ltd.; Nelson Island Sea Farms Ltd.; Taylor Shellfish Canada ULC

PROJECT LEAD: Chris Pearce (DFO – PBS)

PROJECT TEAM: Svetlana Esenkulova, Nicky Haigh (Microthalassia Consultants Inc.); Laurie Keddy, Erin McClelland, Kristi Miller, Amy Tabata (DFO – PBS); Barb Cannon (Creative Salmon Company Ltd.); Tim Lelliott (Grieg Seafood BC Ltd.); Peter McKenzie (Mainstream Canada); Gordy McLellan (Mac's Oysters Ltd.); Alex Munro (Taylor Shellfish Canada ULC); Yves Perreault (Little Wing Oysters Ltd.); Rob Saunders (Island Scallops Ltd.); Glenda and Henry Syrjala (Cleanwater Shellfish Ltd.); Dean Trethewey (Marine Harvest Canada Inc.); Bill Vernon (Nelson Island Sea Farms Ltd.)

CONTACT: Chris.Pearce@dfo-mpo.gc.ca



Bloom of *Heterosigma akashiwo* in Kyuquot Sound, British Columbia. *Photo: Nicky Haigh (Microthalassia Consultants Inc.)*

ABORIGINAL PRINCIPLES FOR SUSTAINABLE AQUACULTURE PROGRAM PHASE 3: BRANDING AND MARKETING

APSA Certification Logo. *Credit: Aboriginal Aquaculture Association*

The Aboriginal Aquaculture Association (AAA) has developed the Aboriginal Principles for Sustainable Aquaculture (APSA) to further develop an integrated, aboriginal management and certification program for aquaculture in Canada.

Phase 2 of the project focuses on the audit processes required to lend credibility to the APSA. It includes a defendable audit approach and the use of qualified, professional auditors to determine the level of conformance to the Association's Standard. Currently work continues on Phase 2 of the project.

This project, Phase 3 will expand the reach of APSA and move the program closer to the market place by establishing a brand and a marketing strategy which would include promotion of the program to First Nations and industry. The inclusion of First Nation values into a management framework has not yet been fully realized and as a consequence has resulted in much of the developmental constraints faced by industry in Canadian coastal regions, particularly BC.

This project will further engage First Nations, industry and retailers with the result that all aquaculture industry sectors will have the ability to participate and demonstrate sustainability with respect to First Nation values, expectations and interests.

JUNE 2011 - DEC. 2012

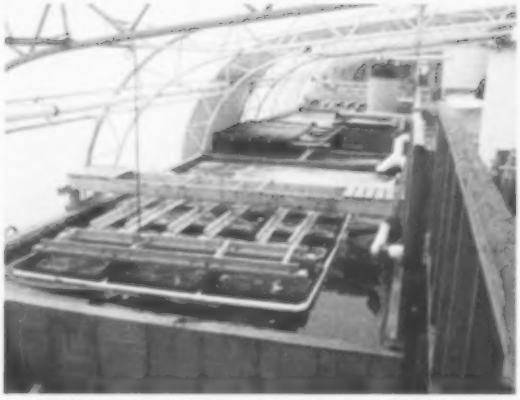
FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Chief Richard Harry (AAA)

COLLABORATORS: Mainstream Canada

CONTACT: richard@aboriginalaquaculture.com

INTEGRATING RED MACROALGAE INTO LAND-BASED MARINE FINFISH AQUACULTURE



LEFT: Tumble culture concrete for growing red macroalgae in effluent from halibut. **MIDDLE:** Dr. Jang Kim holding *Palmaria palmata*. **RIGHT:** *P. palmata* in close up. *All Photos: Peter Corey (Scotian Halibut Ltd.)*

Land-based 'closed' marine culture systems seem to some to be an attractive alternative to open sea-cage systems, preventing escapees and allowing proper management of solid waste and pathogens. However, the eutrophication risk from dissolved nitrogen (N) and phosphorus in the effluent remains unless plants are integrated into the production cycle. We quantified N uptake by Irish Moss (*Chondrus crispus*) and Dulse (*Palmaria palmata*) between 1 – 18 °C in tumble culture in lab- and also pilot-scale trials at Scotian Halibut Ltd. Experimental factors included stocking density, light intensity, nutrient concentration and intermittent aeration. We estimate bioremediation of 50% of the N excreted by 100 tonnes of farmed halibut in winter and summer could be achieved by growing 100 and 600 tonnes of macroalgae, respectively.

Electricity/compressed air costs and rearing space requirements for tumble culture indicate the integration of red macro-algae on land-based farms could only be commercially viable if value could be added to the fresh Dulse or Irish Moss.

MAR. 2009 - NOV. 2012

FUNDED BY: NSERC Strategic Grant

PROJECT LEAD: Jim Duston

PROJECT TEAM: D. Garbary (StFX); P. Corey (Scotian Halibut Ltd.); J. Manriquez, S. Caines, J. Kim, B. Prithiviraj (Dalhousie U.)

COLLABORATORS: Scotian Halibut Ltd.

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BROWN ALGA CULTURE TRIALS ON THE GASPÉ PENINSULA AND THE MAGDALEN ISLANDS, QUÉBEC: PRE-INDUSTRIAL SCALE-UP IN OPEN-WATER AND SEMI-ENCLOSED ENVIRONMENTS OF MUSSEL FARMS

With the work done since 2006 in collaboration with Les Gaspésiennes inc., a number of steps towards mastering brown algae culture techniques have been completed. These include artificial induction of sporogenesis, gametophyte culture *in vitro*, routine production of 2 mm plants in four weeks, the ability to maintain cultures below the surface to protect against drifting ice and unfavourable surface layer conditions in the summer, and at-sea transfer of 2 mm plants in late autumn to obtain yields of 2 to 4.5 kg wet weight by meter of line in early July. These results were obtained from small-scale trials in Paspébiac, Québec, but as yet, it is not known if they can be reproduced on a larger scale or in other culture environments; recently, interest in kelp culture was expressed by Magdalen Islands mussel producers. The work that was done in the two last years on *Saccharina longicruris* culture was designed to answer the following questions: 1) are culture yields measured in 2008 – 2009 reproducible; 2) are small-scale yields (one 50 m longline) reproducible on a pre-industrial scale; 3) are yields obtained in a small semi-exposed culture site in an open environment reproducible in the Magdalen Islands lagoons; 4) when is the best time to transfer plants at sea; 5) is there a threat that algae grown in the Magdalen Islands lagoons be colonized by the bryozoa *Membranipora membranacea*; 6) what changes have to be made to a mussel farm to incorporate kelp culture; and 7) for larger scale operations, what are the production costs for hatchery plants and how much time is associated to the work at-sea?

APR. 2010 - MAR. 2012

FUNDED BY: DFO – Aquaculture Research and Development Program (ACRDP) **CO-FUNDED BY:** SODIM; Ministère du Développement Économique, Innovation et Exportation (MDEIE)

PROJECT LEAD: Louise Gendron (DFO)

PROJECT TEAM: Éric Tamigneaux (UQAR); Bruno Myrand (Centre maricole des Iles-de-la-Madeleine (CeMIM))

COLLABORATORS: Les Gaspésiennes inc., Les Moules de culture des Îles inc.

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ASSESSMENT OF THE EUROPEAN GREEN CRAB AS A FISHMEAL REPLACEMENT FOR SALMONID AQUACULTURE DIETS

This project will provide the preliminary data to adapt a fisheries approach to mitigate two growing concerns: 1) the management of a non-native invasive species; and 2) the increasingly costly exploitation of wild-caught fish for commercial diets used in aquaculture industries.

Specifically, this project will provide catch data that will be used to develop a fisheries plan to control a nuisance species and produce a feed ingredient that can partially substitute wild-caught fishmeal in commercial salmon diets for the maritime region. The European Green Crab, an invasive alien species that has been negatively affecting several commercial fisheries and ecosystems in PEI, is high in protein and carotenoids making it a good candidate replacement for fishmeal.

MAY 2012 - MAY 2013

FUNDED BY: Innovation PEI

PROJECT LEAD: Sophie St-Hilaire (UPEI)

PROJECT TEAM: Mary McNiven, Pablo Quijon, Jeff Davidson (UPEI)

COLLABORATORS: Fran Hansen (PEI Shellfish Association)

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DEVELOPMENT OF HEALTH PRODUCTS DERIVED FROM ATLANTIC CANADA BIO-RESOURCES — NUTRITIONAL ANALYSIS OF FEEDS CONTAINING SDA-ENRICHED OIL FOR ATLANTIC SALMON AQUACULTURE

Like all vertebrates, fish have a limited ability to synthesize linoleic (18:2n-6) and linolenic (18:3n-3) acid. These two fatty acids are important because they are precursors of C_{20} and C_{22} polyunsaturated fatty acids (PUFA). The desaturation and elongation activities required for C_{18} PUFA synthesis from shorter carbon chain precursors are minimal in these animals. As a result, these C_{18} fatty acids must come from the diet. Stearidonic acid (SDA, 18:4n-3) is an intermediary in the biosynthetic conversion of linolenic acid (LNA, 18:3n-3) into eicosapentanoic acid (EPA, 20:5n-3) which can lead to tissues enrichment with carbon-20 and carbon-22 (C_{20} and C_{22}) fatty acids. We are currently testing a new oil (Ahiflower™ oil) that is naturally rich in stearidonic acid and that could be used as a partial or complete replacement for traditional fish oil. It is well-known that availability of fish oil is decreasing while its demand is increasing. Also, fish oil often contains organic contaminants. Ahiflower™ oil can therefore mimic the beneficial effects associated with n-3 PUFA in fish oil.

JAN. 2008 – DEC. 2013

FUNDED BY: ACOA – AIF **CO-FUNDED BY:** UMCM; CZRI; UMCS

PROJECT LEAD: Sébastien Plante (UMCS)

PROJECT TEAM: Marc Surette, Martin Fillion (UMCM)

COLLABORATORS: France Béland (CZRI)

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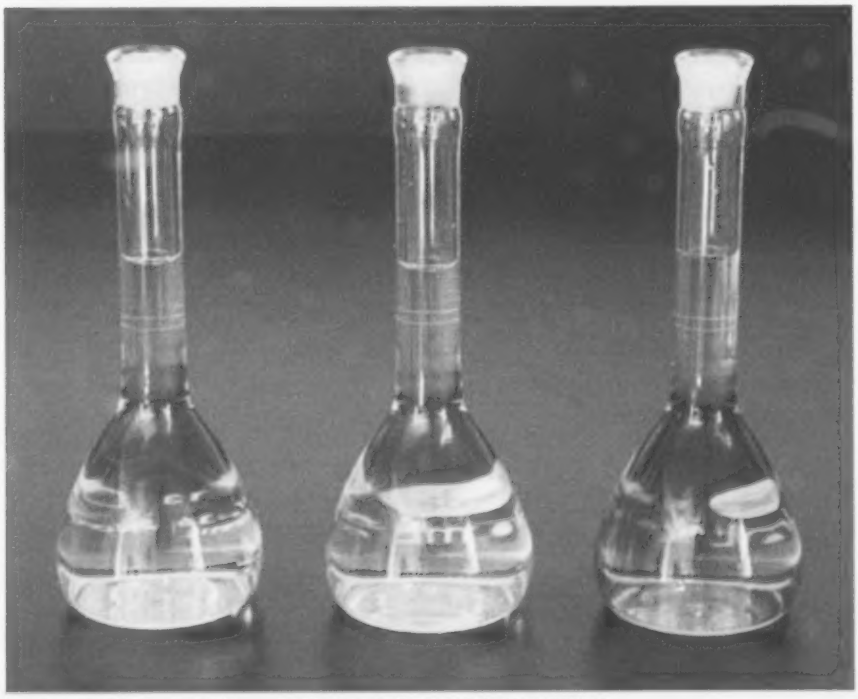

FROM LEFT TO RIGHT: soya oil, Ahiflower™ oil, herring oil. *Photo: Sébastien Plante (UMCS)*

EARLY WARNING AND MITIGATION OF THE IMPACT OF INVASIVE COLONIAL ASCIDIAN TUNICATES

We have recently discovered two non-indigenous ascidians, *Botryllus schlosseri* and *Botrylloides violaceus*, in several harbours on the south coast of Newfoundland. Since both of these species are pests of aquaculture operations elsewhere, we designed an interdisciplinary research program focused on developing gene tools for early detection and determination of ecological factors predicting invasion fitness and future spread. Our goal is to provide information to government agencies responsible for zonal closure and mitigation measures.

The seasonal life cycle of *B. schlosseri* is being determined in Arnold's Cove, Newfoundland, including somatic growth and the rates and timing of asexual and sexual reproduction and larval recruitment. We found that growth, reproduction, and recruitment are constrained by the short growing season in subarctic Newfoundland waters. Somatic growth begins in June, sexual reproduction in late July, and recruitment occurs from August to October; all consistent with temperature-dependent predictions from the temperate native range of *B. schlosseri*. Thus, this species has not become genetically adapted to the short growing season in Newfoundland. However, overwintering survival of colonies is high, contributing to recruitment in the following summer.

Since mitigation is more effective when applied early in an invasion, TaqMan assays are being developed with sufficient sensitivity to detect a single egg or larva in a plankton sample. Assays have been successfully developed for *B. violaceus* and are currently being developed for *B. schlosseri*. Gene sequences will also be used to infer source populations of the Newfoundland invaders.

APR. 2009 – MAR. 2013

FUNDED BY: Natural Sciences and Engineering Research Council of Canada (NSERC) **CO-FUNDED BY:** DFO

PROJECT LEAD: Don Deibel (MUN)

PROJECT TEAM: Cynthia McKenzie (DFO); Matthew Rise, Ray Thompson (MUN)

COLLABORATORS: Newfoundland Aquaculture Industry Association; Newfoundland Department of Fisheries and Aquaculture; DFO

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CANADIAN-AQUACULTURE-STYROFOAM®-ENCASEMENT (CASE)

This demonstration project will encapsulate existing spray foam floats in a novel affordable sea-worthy plastic. It will extend the equipment life span and address aquaculture related pollution due to the breakdown of Styrofoam® in marine environments. The project addresses a long standing challenge for shellfish farming.

Styrofoam® has long been used by the aquaculture industry to provide lightweight inexpensive flotation. Unfortunately the sun and the brine have been breaking it down into microscopic inorganic particles dispersed by wind and tide.

By encapsulating existing Styrofoam® floats in a shell of rugged seaworthy plastic, refurbishing them via the CASE technique can extend the life of the floats for many more decades of use, plus end the breakdown of foam nodules into the water column and onto the beaches.

The exciting aspect of this project is the affordability for operations of all sizes. An AIMAP investment combined with an industry investment will result in the development and adoption of this innovative solution, increasing environmental performance of existing shellfish rafts and providing aquaculture waste control. This will make aquaculture more sustainable by protecting the health of Canada's aquatic ecosystems.

APR. 2012 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** West Coast Spray Foam

PROJECT LEAD: Julia Rendall (Bee Islets Growers Corp.)

PROJECT TEAM: John Shook, Bob Tracy, Roy Tippenhauer, Sandra Wood (Bee Islets Growers Corp.)

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IDENTIFYING CRITICAL ECOLOGICAL THRESHOLDS FOR TUNICATE INFESTATION ON MUSSEL FARMS

Bio-fouling is a well documented shellfish aquaculture industry challenge and the recent invasion of several invasive tunicate species has greatly inflated its impact. The PEI mussel aquaculture industry has been particularly affected by the invasion of four new tunicate species: Clubbed Tunicate (*Styela clava*) in 1998 in the eastern end of the province; Golden Star Tunicate (*Botryllus schlosseri*) in 2001 and 2002 and Violet Tunicate (*Botrylloides violaceus*) were both reported on the north coast of PEI; and in 2004, the Vase Tunicate (*Ciona intestinalis*) was first reported on the east coast of the island. Efforts to control the spread of these tunicate species have been relatively successful, but most mussel producing areas in PEI remain infested with at least one tunicate species. Currently, high pressure water spray is the main technique used by the mussel industry to control tunicate fouling. Lime dipping is also used to control tunicates, particularly the Clubbed Tunicate, on mussel socks. Efforts to develop the most cost-effective treatment strategy are continuing while specific ecological thresholds are not yet established. The establishment of both economical and ecological thresholds is central to the sustainability of the mussel industry in PEI and could lead to the creation of the first Integrated Pest Management approach for Aquatic Invasive Species. The goal of this project is to investigate the ecological impact of tunicate treatment with the following objectives: 1) develop a method to estimate the tunicate biomass on mussel farm structures; 2) develop a model to predict the impact of tunicate fall-off, pre- and post-treatment, on the benthic environment; and 3) assess the impact of tunicate filtration and biodeposition on ecosystem productivity.

In 2011, habitat surveys were conducted in St-Mary's Bay, PEI to describe and evaluate the aquaculture producing and the critical habitat (eelgrass beds and shellfish reefs) areas. These consisted of remote sensing (LIDAR) surveys and direct field validations. Preliminary observations were also made during treatment operations to assess the area affected by the high pressure water treatment system. In addition, data from previous studies were gathered to develop and validate a population dynamic model for the Vase Tunicate.

During the winter of 2012, lab experiments were conducted to assess the impact of decomposing tunicate on the sediment. Field trials were conducted during the summer in St-Mary's Bay to assess the impact of tunicate treatments on the sea floor.

JULY 2011 - MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT LEAD: Thomas Landry (DFO)

PROJECT TEAM: Andrea Locke, Chris McKindsey, Monique Niles, Daniel Bourque, Thomas Guyondet, Luc Comeau (DFO); Jeff Davidson, Thitiwan Patanastienkul (AVC – UPEI); Aaron Ramsay (PEI DFARD)

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ASSESSMENT OF A NEW NATURAL INGREDIENT FOR GROWTH AND PIGMENTATION IN ATLANTIC SALMON FLESH

Farming carnivorous fish depends largely on world fish meal and fish oil supplies. It is now well established that these key ingredients come from a heavily exploited fishery. Great strides have already been made in developing alternate protein and lipid sources.

The pink colour of salmonid flesh is also a key economic issue in fish farming. Currently, this colour is obtained by adding artificial pigments to feed formulations. Although these pigments are considered fit for human consumption, these products require the display of "artificial" or "added colour" label.

The objective of this project was to test the effects of a shrimp hydrolysate added to feed formulation on flesh growth and pigmentation in Atlantic Salmon. In addition to being an excellent source of natural astaxanthin (600 mg/kg), this innovative ingredient is also rich in protein (70%) and lipids (16%). Three feeds were tested: 1) a pigment-free control feed; 2) a shrimp hydrolysate-based feed; and 3) a control feed containing an added artificial astaxanthin source.

APR. 2009 - MAR. 2014

FUNDED BY: ACOA-AIF **CO-FUNDED BY:** CZRI

PROJECT LEAD: Sébastien Plante (UMCS)

PROJECT TEAM: Sébastien Plante (UMCS); Jacques Gagnon, Nadia Tchoukanova (CZRI)

COLLABORATORS: France Béland (CZRI); Mary McNiven (UPEI)

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Colourimeter used to measure the colour in salmon fillets. *Photo: Sébastien Plante (UMCS)*

AQUACULTURE TECHNOLOGY IMPLEMENTATION

Newfoundland Aqua Services Ltd. (NAS) has already undertaken a pilot project to examine technology alternatives and to inform the establishment of a commercial land-based netwashing operation to serve the Coast of Bays finfish aquaculture industry in NL. The pilot project has facilitated an assessment of two of the key pieces of technology (a drum washer and filtration system).

Other major marine finfish aquaculture jurisdictions have moved their netwashing activities onshore to land-based sites to mitigate the biosecurity risk. NAS has recently undertaken a review of netwashing practices and protocols in Norway, New Brunswick and British Columbia, and now plans to implement a land-based netwashing system in the Coast of Bays at a location in Milltown, NL.

NAS decided to move toward purchasing a larger drum washer, 30 m^3 capacity as well as a vacuum bag system that impregnates the nets with anti-foulant evenly and then removes excess anti-foulant from the nets through the vacuum bag system. The vacuum bag technology, recently developed in Norway, will be new to the aquaculture industry in North America.

APR. 2011 - DEC. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** ACOA

PROJECT LEAD: Boyd Pack (Newfoundland Aqua Service Ltd.)

PROJECT TEAM: Ann Strickland, Owen Cox (Newfoundland Aqua Service Ltd.)

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WWW.NEWFOUNDLANDAQUA.COM

Impregnator. Photo: Ann Strickland (Newfoundland Aqua Services Ltd.)

NET DRYING INNOVATION IN AQUACULTURE SERVICING

This project is a component of a multi-year initiative to eliminate open ocean netwashing through the construction of a closed land-based facility. A structured approach has been employed by Newfoundland Aqua Service Ltd. (NAS) to evaluate and adapt the best technologies for each operational component of the commercial land-based facility from net washing, net disinfection, sold waste management, liquid waste management, and net drying.

After the cleaning and disinfection process, nets are treated with copper-based antifoulant and dried before they are ready for use. Previously, NAS relied upon natural air-drying by hanging the nets on large poles out of doors and use of electrical fans in a net drying building to 'blow-dry' nets. This arrangement, which is also utilized in some other jurisdictions, is weather dependent, slow, and not suitable for the requirements and timing of customers.

NAS has investigated drying technologies and has worked closely with Geo-Xergy Systems Inc. of Winnipeg. NAS intends to utilise geothermal sourced heat in the drying process. Geo-Xergy's technology is a cost-effective and environmentally friendly process to dry the treated nets.

The initiative is a key component of biosecurity plans for the industry and a strategic piece of private sector infrastructure required for the salmonid industry.

APR. 2012 - MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP)

PROJECT LEAD: Boyd Pack (Newfoundland Aqua Service Ltd.)

PROJECT TEAM: Boyd Pack, Ann Strickland, Owen Cox (Newfoundland Aqua Service)

COLLABORATORS: Geo-Xergy Systems Inc.

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RESEARCH & DEVELOPMENT COORDINATOR TRAINING IN ENVIRONMENTAL MANAGEMENT SYSTEMS TO ASSIST AQUACULTURE INDUSTRY CERTIFICATION

The level of document systems and record keeping in the small- and medium-sized aquaculture operations that make up the bulk of the sector in Atlantic Canada is not advanced enough to achieve third party certification under most existing or forthcoming standards. The necessity of implementing such a system and having it verified by a consultant auditor would place a heavy financial burden upon these businesses. This project seeks to address that technical gap and alleviate the cost by using the Research and Development Coordinator (RDC) as trained technical resources, available to association members at little or no cost.

It is the mandate of the RDCs to act as scientific and technical resources for association members. The project aimed at training RDCs in ISO 14001 Environmental Management Systems and certification schemes currently available to the industry. ISO 14001 is a set of international standards for the development of environmental management systems and supporting audit programs; and is the standard upon which most third party certification schemes are based. This ISO based training will provide the RDCs with the expertise to assist Industry in introducing the necessary paperwork systems, and then be able to assess or audit them against a variety of certification standards prior to their actual certification, to discover the "gaps" that need to be addressed.

APR. 2011 - MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Province of Prince Edward Island; Province of Nova Scotia; Province of Newfoundland

PROJECT LEAD: Peter Warris (Prince Edward Island Aquaculture Alliance)

PROJECT TEAM: Peter Warris (PEIAA); Danielle Goodfellow (AANS); Darrell Green (NAIA)

COLLABORATORS: Global Trust Consultants

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DEVELOPMENT OF A COMPREHENSIVE FISH WASTE UTILIZATION SYSTEM THAT PRODUCES TWO PRODUCTS: NUTRACEUTICAL FISH OIL AND ORGANIC FISH SOIL AMENDMENT

West Coast Fishculture Ltd. (WCF), located at Lois Lake, BC, has a Steelhead Trout, *Oncorhynchus mykiss*, production facility consisting of a hatchery, a grow-out system and a processing plant. Prior to this project, WCF identified several options for recovering valuable products from fish farming and processing wastes. This project developed those ideas from concept to commercialization. It makes WCF a unique aquaculture operation through its efforts to try to productively utilize 100% of the fish it produces, head, guts, and all.

This waste utilization system delivers the following benefits: 1) the system consistently processes 100% of all waste streams; 2) the system removes high grade fish oil which may be used as fuel, and soon may be approved for nutraceutical applications; and 3) the system converts all remaining waste to soil amendment which has achieved organic certification providing increased value in the market place.

The system is an economically-viable alternative to current methods for disposal of aquaculture wastes such as composting. The WCF waste management system produces value added products from previous waste streams in an environmentally friendly and economically feasible manner.

This demonstration project is a showcase for sustainable fish farming with a 100% waste utilization system and as such is an important step forward for aquaculture sustainability.

APR. 2011 – MAR. 2012

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Agri Sea Biodiesel; CPI Pumps & Irrigation Inc.; Canadian Aqua Start; Little Wing Oysters Ltd.; Mac's Oysters Ltd.; Nelson Island Sea Farms Ltd.; Taylor Shellfish Canada ULC

PROJECT LEAD: Bill Vandevert (West Coast Fish Culture Ltd.)

PROJECT TEAM: Bill Vandevert, Bill Ferris, John Christie, Ward Griffioen (West Coast Fish Culture Ltd.); Joan McKay (J. McKay Aquatech)

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HTTP://SIMPLYFISH.CA/

Fish waste utilization system. Photo: West Coast Fish Culture Ltd.

BC ENVIRONMENTAL MANAGEMENT CODE OF PRACTICE

In the rapidly evolving aquaculture industry and with the recent management change from the provincial to the federal government, the BC Shellfish Grower's Association (BCSGA) has recognized the need to bring the 2001 Environmental Management Code of Practice (EMCP) up-to-date. The first EMCP was finalized in 2001 and although a good piece a work with a lot of merit, there have been some major changes to the industry nationally over the last decade that now need to be addressed by an updated EMCP. Working with shellfish growers, industry associations, government regulators, and other stakeholder groups, this plan will encompass the best practices available and give farmers the tools to compete in a global economy while preserving the values of Canadian sustainability as a responsible user of our ocean resources.

The final results and template from this project will be shared Canada-wide. This will enable a standardized environmental code of practice for shellfish farming that that has been generated at the grass-roots level and will stand up to subsequent scrutiny.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** BCSGA

PROJECT LEAD: Matthew Wright (BCSGA)

PROJECT TEAM: Roberta Stevenson (BCSGA)

COLLABORATORS: Fanny Bay Oysters; Pentlatch Seafoods; Odyssey Shellfish; Georgia Straight; CAIA; Mac's Oysters; Lucky 7 Oysters; Island Sea Farms; Little Wing Oysters; Island Scallops

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IMPACTS OF SHELLFISH AQUACULTURE ON MARINE VEGETATION

Marine vegetation, such as seagrass and seaweeds, form the foundation of many nearshore ecosystems and are considered critical habitat for many ecologically and economically important species. Shellfish aquaculture has the potential to impact marine vegetation in a variety of ways: via waste particles smothering vegetation, increasing water clarity affecting light penetration (thereby enhancing growth of marine vegetation), and eutrophication (fueling growth of epiphytes that compete with the seagrasses). The range of effects of shellfish culture on marine vegetation can be complex; however, our understanding of the interactions between them is limited.

Baynes Sound, BC, is an area of intensive shellfish aquaculture and is therefore an ideal location for this research. In addition, data on the oceanography, plankton, and benthic communities in Baynes Sound have been collected for several years. This project will evaluate changes in marine vegetation and associated communities by measuring the relative biomass of each trophic level (grazing, predatory, invertebrates, and fish) along a gradient of effects from intensive shellfish aquaculture. This approach will provide a quick assessment of ecosystem-level effects that may be induced from shellfish aquaculture activities.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (PARR)

PROJECT LEAD: Hannah Stewart (DFO)

PROJECT TEAM: Terri Sutherland, Beth Piercey (DFO)

COLLABORATORS: Steve Katz (NOAA)

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THE HISTORICAL AND SOCIAL DIMENSIONS OF SALMON AQUACULTURE SCIENCE

A salmon farm. Photo: Stephen Bocking, Trent U.

Salmon aquaculture has been a focus of environmental research for over two decades. In this project I am applying the tools of environmental history and science and technology studies to understand how this research has developed, and the roles it has played in public discussions regarding the industry. Several more specific objectives are also being pursued.

First, I am writing an environmental history of salmon aquaculture science. This history will explore the relations between scientific research and the evolving environmental, social, and political dimensions of the industry.

Second, I am examining how the diverse institutions engaged in environmental research — governments, universities, industry, and public interest organizations — have shaped research priorities, research results, and the application of these results.

Third, I am investigating the movement of scientific knowledge of salmon aquaculture between research sites in Canada, Norway, Ireland, and Scotland.

Fourth, I am examining the prospects for effective science, which is able to contribute to resolution of controversies regarding this industry.

While this project is examining the full range of environmental science relating to salmon aquaculture, a special focus is on research relating to sea lice.

JUNE 2007 – JULY 2014

FUNDED BY: Social Sciences and Humanities Research Council of Canada (SSHRC) **CO-FUNDED BY:** Genome British Columbia

PROJECT LEAD: Stephen Bocking (Trent U.)

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PEOPLE.TRENTU.CA/SBOCKING/BOCKING-SALMON.HTML

SUPPORTING AND ADVANCING KEY CANADIAN AQUACULTURE STANDARDS AND CERTIFICATION INITIATIVES

The purpose of this Canadian Aquaculture Industry Alliance (CAIA)-led project is to test the development of a credible and relevant certification model for application across interested sectors of the Canadian aquaculture industry, assuring buyers and consumers that their farmed seafood has been produced in an environmentally responsible manner, and with best management practices for food safety and quality. The model intends to comprehensively measure industry and farm level performance to allow a certification claim of Responsible Aquaculture Management against established FAO-based criteria.

The past CAIA projects funded by the Aquaculture Innovation and Market Access Program (AIMAP) have successfully promoted understanding, dialogue, and capacity building for all participating stakeholders, and, in particular, have greatly accelerated Canadian industry preparedness for the adoption of third-party certification programs. These projects are directly supportive of CAIA's continuing efforts to build a record of Canadian excellence in these important market access subjects. With support through the AIMAP program, CAIA is pleased to have been able to provide assistance to member companies interested in continuous improvement and third party certification. Past benchmarking projects have been directly relevant to current activities and especially relevant for supporting CAIA's initiative to test the FAO-based Responsible Aquaculture Management certification model.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Newfoundland Aquaculture Industry Association (NAIA); Northern Ontario Aquaculture Association (NOAA); PEI Aquaculture Alliance (PEIAA); BC Salmon Farmers Association (BCSFA); Atlantic Canada Fish Farmers Association (ACFFA)

PROJECT LEAD: Ruth Salmon (CAIA)

PROJECT TEAM: Dave Garforth, Cormac O'Sullivan, Peter Marshall (Global Trust Certification Ltd.); Derek Leebosh,(Environics Research)

COLLABORATORS: Canadian Aquaculture Standards Forum Committee Members (CASF)

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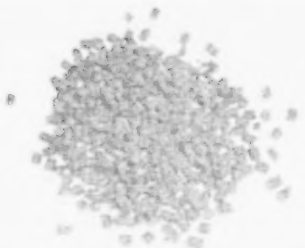
DEVELOPING CAMELINA AS THE NEXT CANADIAN OILSEED



Smolt feed that contains *Camelina*. Photo: Kim Johnstone (Genome Atlantic)

***Camelina sativa* is an ancient plant** that is being explored as a partial replacement of fish meal and fish oil in aquaculture feed. The Camelina Project is a cross-Canada project that is looking at many aspects and uses of the plant, with the Atlantic region focusing on the aquaculture applications.

The Project is assessing the effects of Camelina in the diets of finfish based on fish performance and health. Digestibility trials on diets containing camelina by-products have been completed in Atlantic Cod, Rainbow Trout, and Atlantic Salmon. Feeding trials using different inclusion levels of Camelina meal and/or oil have been completed in cod and Rainbow Trout, and a salmon trial started in August 2012. Results from the feeding trials have demonstrated that trout and cod can tolerate full or partial substitutions of fish oil for Camelina oil, and can tolerate various levels of Camelina meal inclusion. Lipid biochemistry and genomics analyses of fish tissues from these feeding trials are ongoing.

The project is progressing well towards providing information on the performance of fish that are fed Camelina-containing diets. This information can be used to inform the aquaculture industry of the optimal levels of Camelina inclusion in fish feed.

JUNE 2010 – JUNE 2014

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund **CO-FUNDED BY:** Agriculture and Agri-Food Canada – Agricultural Bioproducts Innovation Program; Atlantic Oilseeds; Colorado State University; Giessen University; Genome Atlantic; Genome Prairie; Memorial University of Newfoundland – Ocean Sciences Centre; Minas Seed; Dalhousie Faculty of Agriculture; Nova Scotia Agricultural College; Province of Nova Scotia – Department of Agriculture/Department of Fisheries and Aquaculture; Province of New Brunswick – Department of Agriculture and Aquaculture; Province of Saskatchewan – Ministry of Agriculture; Saskatchewan Canola Development Commission; The Research and Development Corporation of Newfoundland and Labrador; Cooke Aquaculture

PROJECT LEAD: Isobel Parkin, Claude Caldwell

PROJECT TEAM: Matt Rise, Chris Parrish (MUN); Derek Anderson (Dalhousie U.); Dwayne Hegedus (Agriculture and Agri-Food Canada (AAFC)

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WWW.CAMELINAPROJECT.CA

FISHPROBIO: A SUSTAINABLE AND EFFECTIVE ALTERNATIVE STRATEGY FOR PREVENTING MAJOR OPPORTUNISTIC INFECTIONS IN SALMONIDS

In Canada, the booming freshwater aquaculture industry is dominated by salmonid production. Mass production favours the onset of disease, which leads to huge economic losses. However, the use of antibiotics to control bacterial diseases is raising serious concerns because antibiotics persist in organisms and the environment and affect the selection of resistant pathogens. There is an urgent need to develop safe, effective prevention and treatment strategies, while maintaining the industry's economic viability. The probiotic approach clearly meets these criteria. We chose the Brook Trout (*Salvelinus fontinalis*) as a model, as it is the most widely harvested species in Quebec. Our experimental strategy is to collect bacteria naturally present in the skin mucus of healthy fish. The initial results of our approach show that seven bacteria from the fish skin microbiome are strong competition *in vitro* against two opportunistic pathogens (*Flavobacterium columnare* and *F. psychrophilum*), making those very promising probiotic candidates. We successfully tested the curative efficacy of the best probiotic candidate in an in vivo experiment. Infected fish were treated by adding the probiotic on a daily basis. The treatment improved fish survival by 54 to 86% compared to fish in control ponds (infected fish not treated with probiotics).

JAN. 2008 – DEC. 2012

FUNDED BY: NSERC – Strategic Subvention; Société de recherche et de développement en aquaculture continentale (SORDAC); RAQ; Aquaculture Forestville; NSERC – Collaborative Research and Training Experience Program (CRTEP)

PROJECT LEAD: Nicolas Derome (U. Laval)

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DEVELOPMENT OF A BIODIESEL PRODUCTION PROCESS FROM MICROALGAE USING CHEESE WHEY PERMEATE

Reducing the cost of microalgae raw oil could allow the advent of a new fossil fuel competitor on the market and this would help limit the amount of carbon dioxide (CO_2) emitted by mankind into the atmosphere. This must be initiated by the elaboration of new industrial processes allowing the mass production of microalgae oil at lower costs. While the avenue of microalgae biomass production in combination with wastewater remediation has been identified as a cheap route for producing biomass, many factors significantly impair growth and productivity. The aim of the present work is to evaluate another avenue, using a major co-product from the cheese industry, whey, for use in a microalgae-based biodiesel production process. A quick pre-treatment of whey can be realized to produce a concentrated and purified lactose stock, using already available industrial equipment in this industry. Promising results on the use of a selected microalgal strain to grow on lactose in mixo/heterotrophic conditions are presented, as part of an eventual industrial process that would convert it into microalgal oil. Cellular lipid profiles of the microalgae at different growth stages are also investigated to ensure the production of a biodiesel with adequate properties.

SEPT. 2010 – JAN. 2014

FUNDED BY: Fonds de recherche Nature et technologies du Québec (FQRNT); RAQ

PROJECT LEAD: Jean-Michel Girard (U. Sherbrooke)

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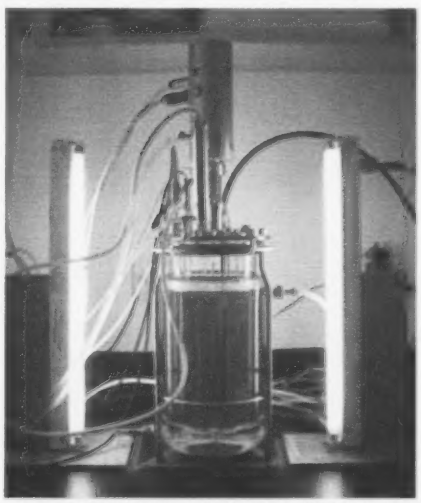

Measuring microalgal growth. Photo: Jean-Michel Girard (U. Sherbrooke)

NOVEL ANTIFOULING TECHNOLOGIES

Invasive tunicates adhering to an experimental underwater structure. *Photo: M. Gerhartz*

The Centre for Biofouling Research at St. Francis Xavier University is a multidisciplinary team researching cost effective and environmentally friendly solutions to manage biofouling. Our goal is to design and demonstrate the effectiveness of biofouling resistant surfaces for submerged surfaces in the ocean, with a particular focus on reducing fouling in cold temperate waters. Our team, which includes expertise on the molecular dynamics of biofilms, microorganisms, biomechanics, marine larval biology, and field experimentation, is using a range of techniques to explore both chemical and physical means to either reduce development or promote release of fouling communities. We are currently focusing on deterrents for invasive tunicates (sea squirts).

APR. 2011 – MAR. 2013

FUNDED BY: Encana **CO-FUNDED BY:** NSERC

PROJECT LEAD: Truis Smith-Palmer (StFX)

PROJECT TEAM: Cory Biship, Edwin DeMont, Darren Derksen, Lori Graham, David Pink, Russell Wyeth (StFX)

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SITES.STFX.CA/BIOFOULING/

DEVELOPMENT OF FEED FOR CULTURING LOBSTER LARVAE FOR SEEDING IN A NATURAL ENVIRONMENT

Since 2002, Homarus Inc., a not-for-profit organization managed by the Maritime Fishermen's Union (MFU), has been collaborating with the Coastal Zones Research Institute Inc. (CZRI) to ensure the production of post-larval lobster for seeding in a natural environment. Current aquaculture techniques produce over 100,000 post-larvae per year. However, larvae production costs remain relatively high. To date, no feed is perfectly suited to the culture of American Lobster larvae. As a result, hatchery-produced lobster larvae are fed with a tri-mix diet made up of frozen Brine Shrimp, commercial Brine Shrimp flakes, and ArteMac™. However, these products are expensive, difficult to obtain (requiring importation) and must be kept frozen until they are used. There is therefore an imminent need to develop a dry, practical diet for lobster larvae. The objective of this research is therefore to develop a dry feed for lobster larvae that would meet their nutritional needs. Producing such a feed would allow and greatly facilitate the implementation of lobster larvae-raising techniques within the industry.

APR. 2010 – MAR. 2012

FUNDED BY: NSERC-CRD **CO-FUNDED BY:** Homarus Inc.; UMCS; UMCM; CZRI

PROJECT LEAD: Sébastien Plante (UMCS)

PROJECT TEAM: Marc Surette (UMCM)

COLLABORATORS: Martin Mallet (Homarus Inc.); Maxime Boudreau (UMCM); France Béland (CZRI)

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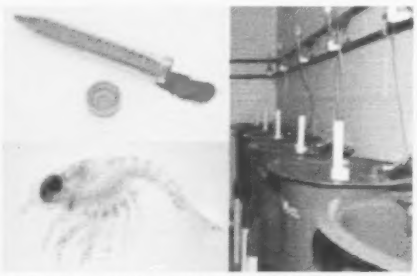

LEFT: Experimental lobster diet. **BOTTOM LEFT:** Early stage of lobster development. **RIGHT:** Experimental tanks. *Photo: Sébastien Plante (UMCS)*

ANAEROBIC DIGESTION OF FISH OFFAL AND SAWDUST

Anaerobic digestion is an attractive option for manure/waste management because of its potential to digest agricultural and industrial residues, while reducing greenhouse gas emissions, mitigating pathogens and odours, and increasing ionized nutrients in the material being digested. This study will test this option by investigating the digestion of fish offal and sawdust using 20-L digesters (microorganisms that break down biodegradable material) under two operational strategies. The digester studies will focus on optimizing biogas/methane production by changing organic loading rates, ratio of fish offal to sawdust, and feeding technique (batch *vs* semi-continuous). The biogas/methane yields determined in this study will be used to assess the economic and performance feasibility of a full scale system.

DEC. 2011 – MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Meeker's Aquaculture

PROJECT LEAD: Doug Geiling (DFO)

PROJECT TEAM: Richard Moccia, David Bevan, Anna Crolla (U. Guelph)

COLLABORATORS: Mike Meeker (Meeker's Aquaculture)

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ASSESSING THE BIOAVAILABILITY OF METHIONINE AND LYSINE FROM DIFFERENT SOURCES

Supplementing synthetic methionine (Met) and/or lysine (Lys) to diets of terrestrial farm animals in order to meet the nutritional requirements for methionine or lysine is a common practice. Different forms of supplemental Met and Lys are produced and commercialized by different manufacturers. Limited information exists on the bioavailability of the different forms of Met and Lys to fish species.

The project involves two separate dose-response feeding trials, in which graded levels of test synthetic amino acids, three methionine sources and two lysine sources, are fed to juvenile Rainbow Trout for 12 weeks. Relative bio-efficacy of test amino acids is to be assessed using a slope-ratio assay method.

MAY 2012 – ONGOING

FUNDED BY: Evonik Industries AG, Germany **CO-FUNDED BY:** OMAFRA

PROJECT LEAD: Christopher Powell, Dominique P. Bureau (U. Guelph)

PROJECT TEAM: Kabir Chowdhury (U. Guelph)

COLLABORATORS: Andreas Lemme (Evonik Industries AG)

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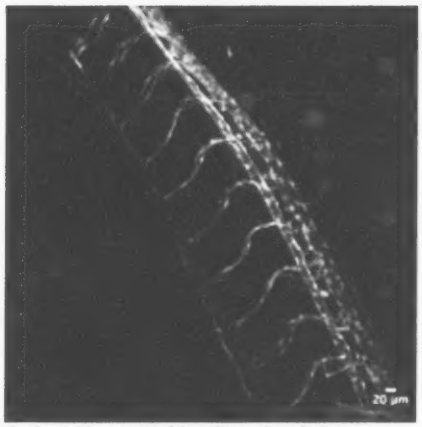
PHYSIOLOGY OF TRIPLOID FISH



Confocal micrograph of the mid-section of a live Tg(flk1:GFP) Zebrafish embryo highlighting its vasculature. *Photo: Chris Small (UNB)*

Triploidy is the only management tool currently available for ensuring reproductive sterility of farmed fish. Sterile populations can be of direct benefit to industry, since sexually mature fish often have reduced flesh quality and poor disease resistance. Sterility also addresses the risk of escaped fish breeding in the wild. However, triploids are rarely used in aquaculture because of performance limitations. Triploid red blood cells (RBCs) are 40-50% larger than diploid RBCs. We are investigating whether this change in cell size, and the associated reduction in cellular surface area per unit volume, affects triploid performance. For instance, increased size may affect RBC passage through narrow capillaries, and reduced surface area may limit ion transfer or respiratory gas exchange across the cell membrane. We are therefore examining the ability of triploid RBCs to maintain their basic structure and ion transport capabilities *in vitro*, and also conducting *in vivo* experiments to look at RBC flow under various conditions of thermal and hypoxic stress. We have adopted Zebrafish as a model species for some of this research because of the availability of stocks with fluorescent RBCs and endothelial linings of their blood vessels. The research will then be extended to Atlantic Salmon.

SEPT. 2012 – ONGOING

FUNDED BY: NSERC **CO-FUNDED BY:** New Brunswick Innovation Foundation (NBIF)

PROJECT LEAD: Tillmann Benfey (UNB)

PROJECT TEAM: Chris Small, Nicole Nader, Bryan Crawford (UNB)

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WWW.UNB.CA/FREDERICTON/SCIENCE/BIOLOGY/FACULTY/BENFEY.HTML

PROTECTIVE BARRIER TO COUNTER SEA OTTER PREDATION

Currently there are very little data on methods to reduce the impact of Sea Otter predation on shellfish farm stocks, as this is a new issue in most aquaculture farm areas on the west coast of Canada. This predation will become more problematic as the otters expand their range into more populated areas of the coast. As an example, stock losses would likely be 80 to 85 percent of standing stock on a Manila Clam farm without protection. Obviously, this would not be viable on a commercial basis.

Nootka Sound Shellfish Ltd. will develop, test and evaluate novel protective barriers to counter Sea Otter predation of Manila Clams which is a serious threat on the North Coast and North Island of the Pacific Region. Experts indicate that this is an increasing and significant challenge for shellfish farmers. Sea Otters eat up to 40% of their body weight daily so a growing population is threatening the long term success of co-located shellfish farms. To respond to this threat, Nootka Sound Shellfish will be designing and demonstrating a two net system using nylon and polypropylene to protect their farm from Sea Otter predation, to achieve clear productivity gains through limiting Sea Otter predation and to maintain the safety of the Sea Otters.

APR. 2012 – MAR. 2013

FUNDED BY: DFO – Aquaculture Innovation and Market Access Program (AIMAP) **CO-FUNDED BY:** Pacific Net & Twine; Summer Breeze Aquaculture Products; Harbour Chandler

PROJECT LEAD: Kevin Vautier (Nootka Sound Shellfish Ltd.)

PROJECT TEAM: Kevin Vautier (Nootka Sound Shellfish Ltd.)

COLLABORATORS: BC Shellfish Growers Association; MV Uchuck III

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A META-ANALYSIS OF ESSENTIAL AMINO ACID REQUIREMENTS IN FISH

Aquaculture feeds are formulated to promote animal's growth and health, while minimizing feed costs and environmental impacts. Achieving maximum efficiency implies a precise knowledge of nutritional requirements, including essential amino acids (EAA). Several reviews have identified great variability in EAA requirement estimates across and within fish species. The construction of a standardized database using information from published studies on EAA requirements of fish and a meta-analysis using this database were the focus of this study. The primary objectives were to estimate EAA requirement of different fish species and identify sources of variability in the estimates of requirement. Over 250 studies on EAA requirement of fish were identified. However, fewer than 25% met the quality criteria required for the database and meta-analysis. The dataset also revealed the high fragmentation of our knowledge in terms of EAA requirement with a few commercially important species represented and limited amount of work on many of the EAA. The meta-analysis revealed the critical importance of proper design of experimental design. Numerous trials did not presenting a clear dose-response and did not allow accurate requirement estimation. Finally, this study also indicates that it is paramount to report basic information such as live weight, experiment duration, temperature, and composition of the diet. Without these parameters, results cannot be standardized across studies, thus resulting in a loss of knowledge.

AUG. 2009 – DEC. 2011

FUNDED BY: NSERC

PROJECT LEAD: Guillaume P. Salze, Dominique P Bureau (U. Guelph)

COLLABORATORS: Margaret Quinton (U. Guelph)

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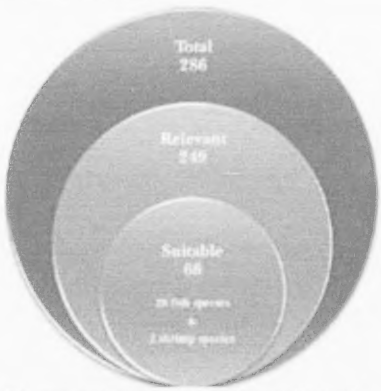


Diagramatic representation of relevant diet studies. *Photo: Guillaume Salze (U. Guelph)*

ORGANIZATIONS

FISHERIES AND OCEANS CANADA (DFO)

DFO delivers programs and services that support the sustainable use and development of Canada's waterways and aquatic resources. On behalf of the Government of Canada, DFO is responsible for developing and implementing policies and programs in support of Canada's scientific, ecological, social and economic interests in oceans and fresh waters. It is DFO's mission to deliver to Canadians the following outcomes:

- Safe and Accessible Waterways;
- Healthy and Productive Aquatic Ecosystems; and
- Sustainable Fisheries and Aquaculture.

In working toward these outcomes, the Department is guided by the principles of sound scientific knowledge and effective management.

DFO is the lead federal department for the sustainable management of fisheries and aquaculture. Responsibility for aquaculture management and development (governance) is shared between the federal, provincial and territorial governments. We work together, with many other partners, to ensure that the legislative and regulatory framework for aquaculture is responsive to the public's and industry's needs.

DFO's aquaculture research aims to address regulatory knowledge gaps, and collaborative research and development with the aquaculture industry. Collaborative research facilitates the transfer of the latest technologies to the aquaculture industry. Research on the environmental effects of aquaculture also provides a solid scientific foundation for the conservation and protection of fish and fish habitat in marine or freshwater ecosystems. On-going research contributes to scientific certainty with respect to aquaculture operations and how they interact with the aquatic environment.

In recent years, DFO's research effort has been directed at understanding environmental effects of aquaculture on freshwater and marine habitat and ecosystems. We also invest in aquatic animal health research to understand how best to prevent, mitigate and treat disease. As species diversification is often seen as a means of increasing Canada's global market share, DFO scientists also play a key role in innovative research.

DFO enables research pertaining to aquaculture in Canada through the implementation of research funding programs. These programs vary in their mandates, resulting in a comprehensive strategy for funding scientific research, development or pre-commercialization, whether the research team be made up of researchers internal or external to the department, as well as differences in their funding envelopes and project timeframes.

The following four DFO programs are currently funding Canadian aquaculture research and development:

PROGRAM FOR AQUACULTURE REGULATORY RESEARCH (PARR)

The Program for Aquaculture Regulatory Research (PARR) is an internal research program for DFO scientists that has funded research projects focused on increasing the relevant science knowledge base that supports and advises informed DFO ecosystem-based environmental regulation and decision making for the aquaculture sector.

Since its inception in 2008 as part of the New Aquaculture Program initiative (now the Sustainable Aquaculture Program), PARR has evolved to target research priorities in consultation with aquaculture regulators and managers that have specifically addressed their regulatory needs. Since 2010, national and regional regulatory priorities have focused research in areas such as: benthic habitat impacts from shellfish culture and marine and freshwater finfish aquaculture to support siting decisions; fish health management through increased understanding of the fate and effects of sea lice treatments on non-target organisms; research on sea lice/farmed/wild salmon interactions to improve sea lice management on farms and mitigate potential impacts on wild salmon populations; shellfish bay-scale carrying capacity; and impacts of shellfish culture on marine vegetation.

Since 2010, PARR has approved and funded over 40 targeted projects for a total value over $5M.

For more information, please visit the PARR website at: www.dfo-mpo.gc.ca/science/enviro/aquaculture/parr-prra/index-eng.asp

AQUACULTURE INNOVATION AND MARKET ACCESS PROGRAM (AIMAP)

In 2008 the Department of Fisheries and Oceans announced a new contribution program to bolster the development, early commercialization and/or early adoption of innovative techniques for the Canadian aquaculture sector. In the five years of the program, $23.5 million was made available for innovation and market access projects with an additional $100 million being leveraged from industry and other funding partners.

The goal of AIMAP is to catalyze aquaculture industry investment from the private sector, as well as other sectors, that will: 1) Improve the competitiveness of a sustainable Canadian aquaculture industry by encouraging an aquaculture sector that continuously develops and adopts innovative technologies and management techniques to enhance its global competitiveness and environmental performance; and 2) Position Canadian aquaculture products as having high value in the market place based on their environmental performance, traceability, and other considerations.

Since 2008, 164 projects have been funded through AIMAP under the following priorities: 1) Sustainable production; 2) Green technology; and 3) Species diversification.

AIMAP focuses on funding projects at the pre-commercialization stage of the research and development continuum.

For more information, please visit the AIMAP website at: www.dfo-mpo.gc.ca/aquaculture/sustainable-durable/innovation-eng.htm

GENOMICS RESEARCH & DEVELOPMENT INITIATIVE (GRDI)

Fisheries and Oceans Canada (DFO) uses genomics for the aquaculture industry and in the management of the wild fishery. These tools lead to better disease identification and control, development of techniques to determine accurately the population structure of wild marine fish and to identify endangered species and minimize illegal or inadvertent harvesting. As an enabling technology, genomics provides powerful tools and precise information to support operational mandates and upon which policy and regulatory decisions can be based.

The GRDI was established for the purpose of building and maintaining capacity inside government departments to do genomics research. Through targeted investments the Initiative has enabled the establishment of critical mass in genomics research that supports innovation in key Canadian sectors, and ensures that federal departments can mobilize their support for the overall, national genomics effort (e.g., projects funded by Genome Canada, CIHR). Programs funded under the GRDI are also used to augment human resources and help create partnerships with other government departments, universities, and industry (where applicable) through the sharing of technology platforms and by collaborating in research areas that cut across traditional departmental sectors.

For information, contact: Mark Hovorka (Mark.Hovorka@dfo-mpo.gc.ca), or visit www.dfo-mpo.gc.ca/Science/biotech/abgrds-srdbfa/index-eng.htm

Further information on priorities, plans, programs and projects can be found on the DFO web site: www.dfo-mpo.gc.ca.

AQUACULTURE COLLABORATIVE RESEARCH AND DEVELOPMENT PROGRAM (ACRDP)

The Aquaculture Collaborative Research and Development Program (ACRDP) is a DFO initiative to increase the level of collaborative research and development activity between the aquaculture industry and the department, and in some instances with other funding partners. The ACRDP teams industry with DFO researchers to undertake research activities that lie within the mandate of DFO but are based on the needs and priorities of the aquaculture industry. The program allocates ACRDP funds to collaborative research projects that are proposed and jointly funded by aquaculture producer partners. The ACRDP funding is approximately $2 million per year and projects are funded through a nationally competitive process.

The key goals of the program are to improve the competitiveness and sustainability of the Canadian aquaculture industry; increase collaborative research between the department and industry; facilitate the process of technology transfer and knowledge mobilization; and increase scientific capacity of the Canadian aquaculture industry for essential aquaculture research and development.

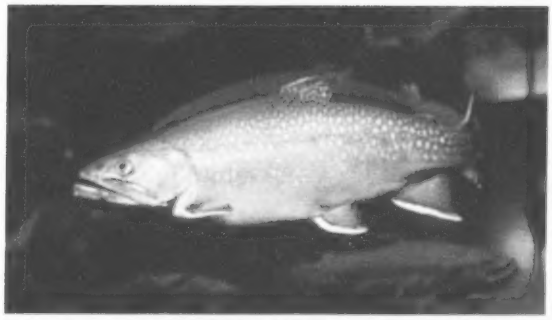
The broad research and development objectives, under which National and Regional priorities are established, are twofold:

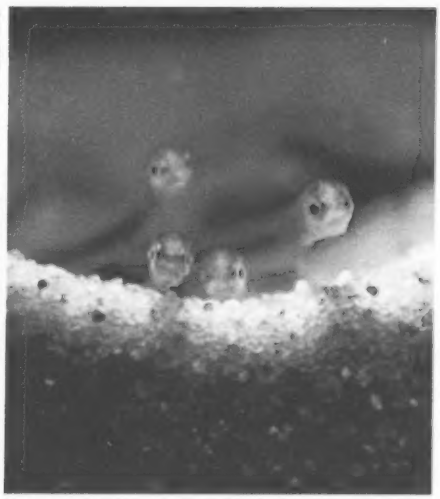
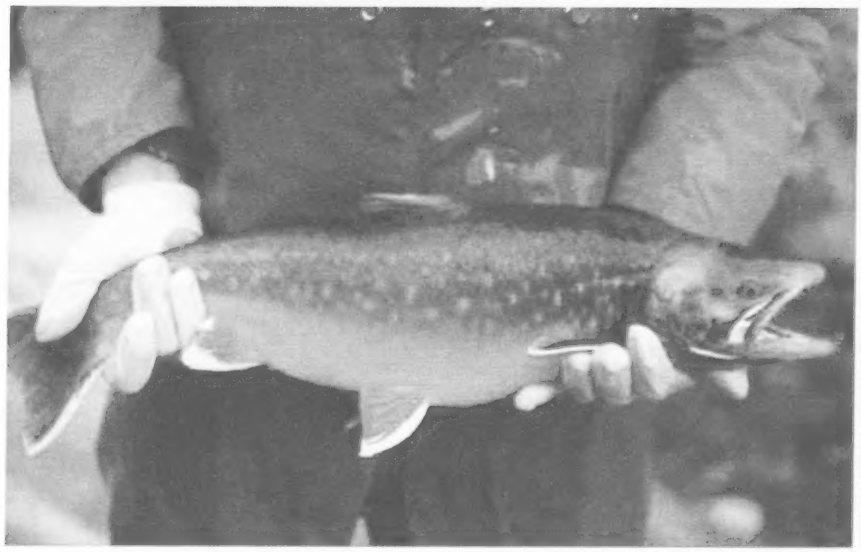
- Optimal fish health
- Industry environmental performance

Since the program's inception in 2001, over 330 projects have been approved and funded.

Over the last five years, DFO has invested over $25 M into research collaborations for the ACRDP.

For more information, please visit the ACRDP website at: www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



THE MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (MINISTÈRE DE L'AGRICULTURE, DES PÊCHERIES ET DE L'ALIMENTATION DU QUÉBEC – MAPAQ) AND MERINOV

The Ministry of Agriculture, Fisheries and Food (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec – MAPAQ) promotes sustainable development and competitiveness of fisheries and aquaculture sector in Quebec. MAPAQ contributes, with its partners, in the implementation of strategies and programs to promote innovation.

Through Innovamer, its financial support program, MAPAQ supports research and development technology transfer activities, technical assistance services, monitoring services for aquaculture and environmental data as well as initiatives to disseminate information. It encourages collaboration between industry, institutions, and organizations in R&D.

MAPAQ finances the fund dedicated to research and transfer in freshwater aquaculture managed by the inland aquaculture research and development corporation (Société de recherche et de developpement en aquaculture continentale Inc. – SORDAC). MAPAQ also funds organizations active in R&D such as Merinov and the Salmonid Selection and Transfer Centre (Centre de transfert et de selection des salmonides – CTSS), and sits on their administration boards.

Merinov, the Quebec Innovation Centre in Aquaculture and Fisheries, was established in June 2010 by MAPAQ, the Cégep de la Gaspésie et des Îles, and the University of Quebec at Rimouski (UQAR). The center was established by regrouping well-recognized entities and teams:

- MAPAQ Centre for Mariculture in the Magdalen Islands (Centre maricole des Îles-de-la-Madeleine – CeMIM)
- MAPAQ Marine Aquaculture Centre in Grande-Rivière (Centre aquacole marin de Grande-Rivière – CAMGR)
- MAPAQ Aquatic Products Technology Centre in Gaspé (Centre technologique des produits aquatiques – CTPA)
- Halieutec College, a center for technology transfer from Cégep
- research teams from UQAR

Merinov provides innovation to fishing industry and aquaculture throughout the province of Quebec. The Centre conducts applied research, experimental development and technology transfer to generate new knowledge and technologies useful to the fishing, aquaculture and aquatic product processing industries. It provides technical assistance to businesses throughout Quebec and is involved in the monitoring and dissemination of information.

Merinov has four centers in the maritime region equipped with basin rooms, pilot plants, laboratories and versatile equipment. It has boats and measuring equipment for operations at sea and in lagoons. Merinov relies on approximately 90 employees recognized for their multidisciplinary expertise, know-how and high quality work in the development of innovative solutions. They work with several organizations in the fisheries and aquaculture sector as well as Quebec and foreign universities.

NSERC INVESTMENTS IN AQUACULTURE

Fuelled by the federal government's commitment to address the innovation needs of fisheries and related industries, investments in aquaculture research by the Natural Sciences and Engineering Research Council (NSERC) and its partners in industry and government are building a strong industry.

NSERC support to research and innovation in aquaculture

NSERC invested over $4.3 million in 2011-12, towards collaborative aquaculture research partnerships. Funding for Canadian universities and colleges to undertake collaborative R&D with the aquaculture industry is available through a variety of established and new NSERC grants. These were created to help connect researchers with industry in order to meet the innovation needs of the aquaculture sector, and to train the next generation of researchers, both for university and private sector research.

By connecting researchers to Canadian companies, NSERC is helping to spur innovation. Close to 1700 new partnerships have been formed 1between university researchers and Canadian companies with the help of NSERC's Engage Grant Program (EGP). This program provides grants of up to $25,000 to have researchers work for six months on solving company-specific technological challenges. This type of arrangement can also help build a foundation for longer-term research relationships.

Engage Grants are one initiative under NSERC's Strategy for Partnerships and Innovation (SPI). This industry-driven Strategy seeks to facilitate collaborative research between academia and industry and has resulted in the following changes at NSERC since 2009:

- Structured business development events supported at the regional level by NSERC's five regional offices (Atlantic, Quebec, Ontario, Prairies and Pacific), who offer introductions and assistance to researchers and companies looking to work together successfully.
- Grant support for project management within NSERC's partnership grants;
- Support for market studies to assist in commercializing promising inventions and to inform research directions within targeted NSERC grants; and
- Changes to NSERC's intellectual property policy to expand arrangement options between industry and post-secondary institutions, including assignment of IP rights to industry partners.

In addition, NSERC has widened the range of funding opportunities for businesses that want to tap into expertise in Canada's community colleges and CÉGEPs. New grants are available for colleges to build a technology access centre to help companies access a college's expertise and facilities; work with a university partner to commercialise technologies; or have college experts undertake short-term work to address company-specific R&D challenges.

NSERC's suite of longer-term granting options remains a powerful tool for projects with multiple industrial partners and longer time frames: Collaborative Research and Development Grants, Industrial Research Chairs and strategic programs continue to receive strong applications and see positive results.

NSERC: Open for Research and Open for Business

Over the last three years, new flexible options, combined with NSERC's flagship suite of grants, have helped more companies than ever before work with researchers to leverage their R&D dollar. Today over 2,400 companies are working through NSERC to establish critical research relationships, develop new and enhanced products and services, and discover new business opportunities.

To learn more about how NSERC can help you, visit (www.nsercpartnerships.ca), or contact the Research Partnerships team at 1-877-454-1767 or by email at: rpp@nserc-crsng.gc.ca.

NSERC CRSNG

NRC IRAP ENABLES SMALL- AND MEDIUM-SIZED AQUACULTURE BUSINESSES SUCCEED THROUGH INNOVATION

NRC Industrial Research Assistance Program

Delivered by a network of over 210 professionals located in more than 100 communities across Canada, the National Research Council Canada Industrial Research Assistance Program (NRC IRAP) supports the needs of small- and medium-sized enterprises (SMEs) engaged in innovative or technology-driven activities.

The Program provides a suite of advisory services, networking and linkages, and non-repayable financial assistance to SMEs. These services are adapted to the SMEs' industrial, socio-economic and geographic make-up in order to provide a customized response to their development needs.

In 2011, NRC IRAP was selected to run the three-year Digital Technology Adoption Pilot Program (DTAPP) as part of the Government of Canada's Digital Economy Strategy. DTAPP represents a significant investment into the Canadian economy in an effort to increase the productivity growth of SMEs in Canada across all sectors through the adoption of digital technologies.

Since April 1, 2011, NRC IRAP has provided approximately $2.5M in financial support to aquaculture SMEs across Canada to assist them in their new product and process development, improvement, and adoption initiatives. Here are some examples of program assistance provided to the aquaculture sector during this period:

NRC IRAP supported Red Hat Co-operative on the development of a framework to quantify growing and operating conditions and objectively assess the impact of using the effluents from an aquaculture facility to enable themselves and other aquaponic growers to better analyze their system efficiencies and economics. Assessment of the aquaponics system must consider the related inputs such as nutrients, water, utility, waste-management and labour costs. The framework will facilitate the development of water and energy balance information and benchmarking parameters will help determine the net benefit of combining aquaculture with hydroponics. For more information contact K. B. Takeda (kbt@trimarkeng.com).

Microthalassia Consulting Inc. received NRC IRAP assistance to develop and enhance a harmful algae monitoring program (HAMP) on the British Columbia Coast. This project allowed their president to hire and train a highly skilled technician in the methodologies for identification of harmful marine microalgae. They also looked at new services and products that the firm could commercialize in the near future to support to BC's aquaculture industries. The firm has now initiated an ACRDP project with the Department of Fisheries and Oceans (DFO) to further develop their HAMP. For further information please contact Nicky Haigh (microthalassia@telus.net).

For more information on the program and to contact your local NRC IRAP Industrial Technology Advisor, visit: www.nrc.gc.ca/irap

SUMMARY OF ACOA'S ROLE AND INVESTMENTS IN ATLANTIC CANADA'S AQUACULTURE INDUSTRY

Established in 1987, the Atlantic Canada Opportunities Agency (ACOA) is the federal department responsible for the Government of Canada's economic development efforts in the provinces of New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador. With offices throughout Atlantic Canada, ACOA works with business and communities to make Atlantic Canada's economy more innovative, productive and competitive. In addition, ACOA ensures that Atlantic Canada's interests are reflected in both the policies and programs developed by other departments and agencies of the federal government.

ACOA has a broad mandate to increase employment opportunities and earned income in the Atlantic region. The Agency has identified aquaculture as one of several strategic sectors for Atlantic Canada. Through the Atlantic Innovation Fund (AIF) and the Business Development Program (BDP), ACOA has worked in partnership with industry stakeholders to make investments in innovation and infrastructure that build upon the aquaculture industry's competitive advantages. For instance, over the last 10 years, ACOA has made AIF contributions towards the following R&D aquaculture projects:

Aquaculture R&D Projects related to fish

- Genome Atlantic (Pan Atlantic): Atlantic Cod genomics and broodstock development to enhance the commercialization of the cod aquaculture industry.
- University of New Brunswick (NB): Integrated multi-trophic aquaculture research and development to mitigate the environmental impact of marine cage culture
- University of New Brunswick (NB): Effluent treatment system for land based aquaculture to mitigate effluent discharge
- Novartis Animal Health Canada (PEI): Platform development and DNA vaccine for koi herpes virus
- Université de Moncton (NB) : Broodstock research and development related to high pedigreed Arctic Charr to enhance commercialization opportunities
- Scotian Halibut Limited (NS): Develop certified Halibut broodstock to enhance commercialization opportunities
- Huntsman Marine Science Centre (NB): Develop an Atlantic Salmon brood stock facility to enhance commercialization opportunities
- Research Productivity Council (NB): Develop a new fish pathogen diagnostic tool for the aquaculture industry
- Memorial University (NL): Support for Atlantic Cod broodstock development and fish health management protocols to enhance commercialization opportunities for the aquaculture industry.
- Atlantic Veterinary College (PEI): Create a Centre for Aquatic Health Sciences to support the regions aquaculture industry
- Genome Atlantic (PEI): Development of Camelina as a feed supplement for the aquaculture industry
- Aqua Bounty Canada Inc. and Aqua Bounty Farms Inc. (PEI): Generate technology to produce reproductively sterile Atlantic Salmon
- Atlantech Engineering & Associates Incorporated (PEI): Advancing water recirculation and effluent treatment technology for the land-based aquaculture industry
- Solarvest (PEI) Inc.: Microalgae oils for salmon feed nutraceutical application
- Cooke Aquaculture Inc. (NB): Development and implementation of aquaculture stock traceability
- Novartis Animal Health Canada Inc. (PEI): Mitigation of infectious salmon anemia (ISA) by vaccination and genetic selection

Aquaculture R&D Projects related to shellfish and seaweeds

- PEI Aquaculture Alliance (PEI): Management of invasive species (e.g., tunicates) fouling aquaculture farms
- Université de Moncton (NB): Technology and services to enhance the commercialization of the shellfish (e.g., oysters) industry
- Acadian Seaplants Limited (NS): Cultivate seaweed biomass for human food and biomass for active compounds for use in various sectors (e.g., agriculture, nutrition)

For information contact: AIF and BDP, please consult: http://www.acoa-apeca.gc.ca

RESSOURCES AQUATIQUES QUÉBEC (RAQ)

Ressources Aquatiques Québec (RAQ) is a strategic cluster supported by the Fonds de recherche du Québec — Nature et technologies (FRQNT). Its regular members are affiliated with Université du Québec à Rimouski, Université Laval, Université du Québec à Chicoutimi, Université de Sherbrooke, Université de Montréal, Université du Québec à Montréal, the École Polytechnique de Montréal, INRS-IAF, McGill University and the CÉGEP de la Gaspésie et des Îles. Several researchers from various federal and provincial government departments, as well as researchers from other Canadian provinces or other countries, are also affiliated as government researchers or researchers from outside Quebec. Its members carry out aquaculture- and recreational/commercial fishery-related research projects.

In aquaculture, RAQ researchers focus on fish, mollusc, crustacean, and microalgae/macroalgae production and participate in joint projects using their expertise in engineering, genomics, quantitative genetics, health, microbiology, physiology, nutrition, behaviour and ecology.

RAQ has always had very close relations with the Quebec aquaculture sector, including the Société de développement de l'industrie maricole (SODIM), the Société de recherche et de développement en aquaculture continentale (SORDAC), the Centre de transfert et sélection des salmonidés (CTSS) and several private sector and government partners.

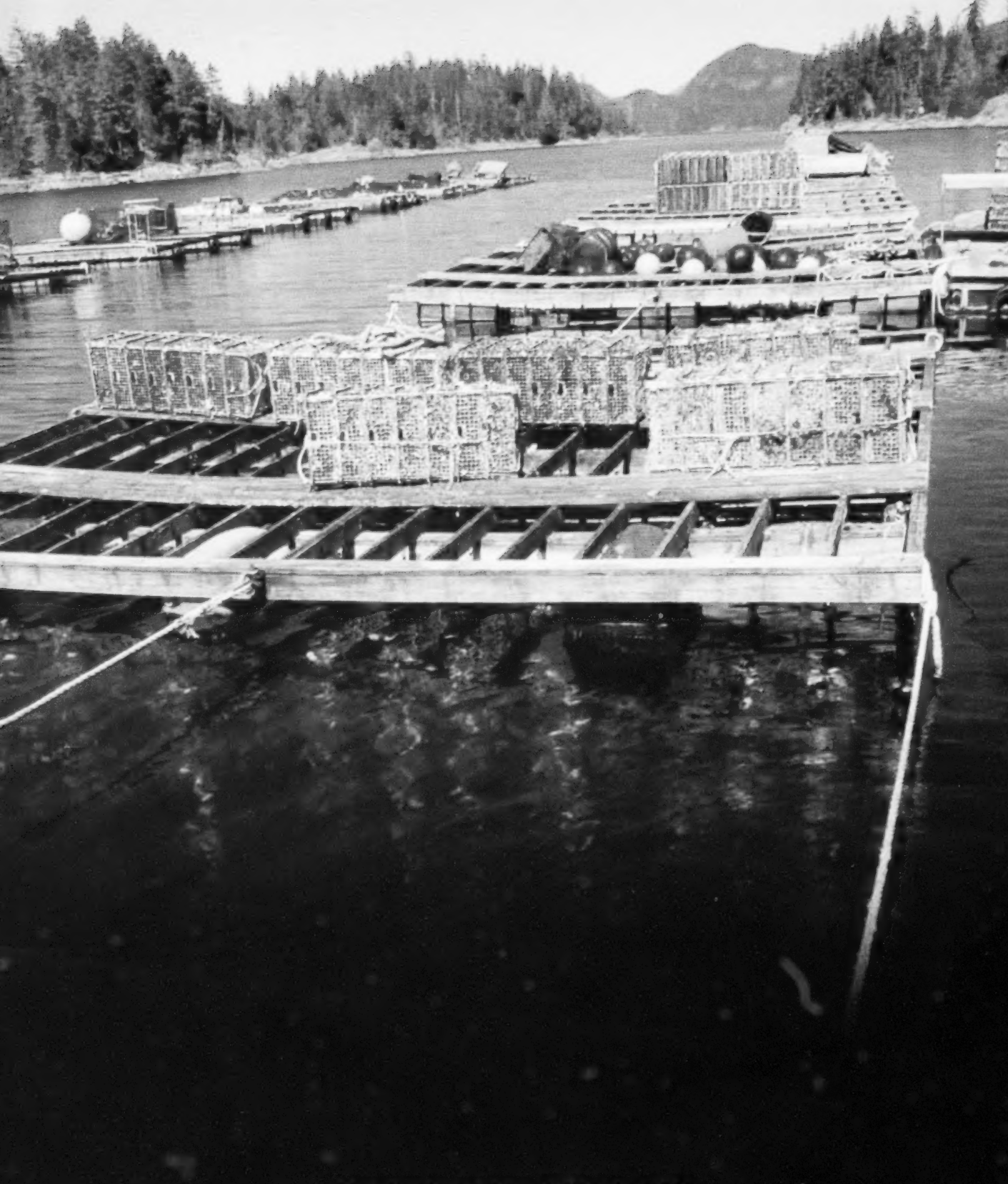
Information: Céline Audet, PhD, Scientific Director (celine_audet@uqar.qc.ca)

Web site: http://raq.uqar.ca/

Ressources Aquatiques Québec RAQ

GLOSSARY

AAA	Aboriginal Aquaculture Association
AAFC	Agriculture and Agri-Food Canada
AANS	Aquaculture Association of Nova Scotia
ACFFA	Atlantic Canada Fish Farmers Association
ACOA	Atlantic Canada Opportunities Agency
ACOA-AIF	Atlantic Canada Opportunities Agency – Atlantic Innovation Fund
ACRDP	Aquaculture Collaborative Research and Development Program
AIMAP	Aquaculture Innovation and Market Access Program
AIS	aquatic invasive species
APSA	Aboriginal Principles for Sustainable Aquaculture
AVC	Atlantic Veterinary College (UPEI)
BAMP	Broughton Archipelago Management Plan
BC	British Columbia
BCSFA	BC Salmon Farmers Association
BCSGA	BC Shellfish Grower's Association
BCWD	bacterial cold water disease
BKD	bacterial kidney disease
BIO	Bedford Institute of Oceanography (DFO)
C-CORE	Centre for Cold Ocean Resources Engineering
CAAR	Coastal Alliance for Aquaculture Reform
CAHS	BC Centre for Aquatic Health Sciences
CAIA	Canadian Aquaculture Industry Alliance
CASF	Canadian Aquaculture Standards Forum
CCFRN	NSERC Canadian Capture Fisheries Research Network
cDNA	complementary DNA (deoxyribonucleic acid)
CÉGEP	Collège d'enseignement général et professionnel (English : General and Vocational College)
CeMIM	Centre maricole des Iles-de-la-Madeleine
CERC	Canada Excellence Research Chair
CFI	Canadian Foundation for Innovation
CFIA	Canadian Food Inspection Agency
CHONe	Canadian Healthy Oceans Network
CIHR	Canadian Institute of Health Research
CIMTAN	Canadian Integrated Multitrophic Aquaculture Network
CMN	Canadian Museum of Nature
CRI	Canadian river institute
CRTEP	[NSERC] Collaborative Research and Training Experience Program
CSR	Centre for Shellfish Research (VIU)
CTSS	Centre de transfert et sélection des salmonidés
CZRI	Coastal Zones Research Institute Inc.
DFA	Department of Fisheries and Aquaculture (NL)
DFA-FTNOP	DFA Fisheries Technology and New Opportunities Program
DFARD	Fisheries, Aquaculture and Rural Development (PEI)
DFO	Fisheries and Oceans Canada
DFO-EAS	(DFO) Economic Analysis and Statistics
DHA	docosahexaenoic acid
EMCP	Environmental Management Code of Practice
FAO	[United Nations] Food and Agriculture Organization
FODAR	Fonds de développement académique du réseau des Universités du Québec
FONCER	NSERC – Programme de formation orientée vers la nouveauté, la collaboration et l'expérience en recherche
FQGZ	Fédération Québécoise des Gestionnaires de Zecs
FQRNT	Fonds de recherche Nature et technologies du Québec
FVCOM	Finite Volume Coastal Ocean Model
GRDI	Genomics Research and Development Initiative
HAMP	Harmful Algae Monitoring Program
HMSC	Huntsman Marine Science Centre
HSP	heat shock protein
IFREMER	French Research Institute for Exploration of the Sea (Institut français de recherche pour l'exploitation de la mer)
IHNV	infectious haematopoietic necrosis virus
IMTA	Integrated Multitrophic Aquaculture
INRS-IAF	Institut national de la recherche scientifique – Institut Armand-Frappier Centre
IOS	Institute of Ocean Sciences (DFO)
IPSFAD	Interprovincial Partnership for Sustainable Freshwater Aquaculture Development
IRAP	NRC Industrial Research Assistance Program
ISA(v)	infectious salmon anemia (virus)
ISMER	Institut des sciences de la mer de Rimouski
ISO	International Organization of Standards
IUEM	Institut universitaire européen de la mer
LIDAR	Light Detection and Ranging
MAFRI	Manitoba Agriculture, Food and Rural Initiatives
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MB-CMAF	Manitoba – Canadian Model Aqua-Farm
MDEIE	Ministère du Développement économique, de l'Innovation et de l'Exportation
MFU	Maritime Fishermen's Union
MRNF	Ministère des Ressources naturelles et de la Faune du Québec
MUN	Memorial University of Newfoundland and Labrador
NAIA	Newfoundland Aquaculture Industry Association
NB	New Brunswick
NB DAA	New Brunswick Department of Agriculture and Aquaculture (now New Brunswick Agriculture, Aquaculture and Fisheries)
NBDAAF	New Brunswick Agriculture, Aquaculture and Fisheries
NBIF	New Brunswick Innovation Foundation
NBPSGA	New Brunswick Professional Shellfish Growers Association
NL	Newfoundland and Labrador
NOAA	US National Oceanographic and Atmospheric Administration *OR* Northern Ontario Aquaculture Association
NRC	National Research Council
NS	Nova Scotia
NSERC	National Science and Engineering Research Council
NSERC-USRA	NSERC Undergraduate Student Research Awards Program
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs (now Ontario Ministry of Agriculture and Food)
OMNR	Ontario Ministry of Natural Resources
OMoE	Ontario Ministry of the Environment
OSC	Ocean Science Centre (MUN)
PAGE	polyacrylamide gel electrophoresis
PARR	Program for Aquaculture Regulatory Research
PBS	Pacific Biological Station (DFO)
PCR	polymerase chain reaction
PE (PEI)	Prince Edward Island
PIDDAED	Partenaire interprovincial pour le développement durable de l'aquaculture d'eau douce
PEIAA	Prince Edward Island Aquaculture Alliance
PIT	passive inductive transponder
PSIIRI	Programme de soutien à des initiatives internationales de recherche et d'innovation
PVC	polyvinyl chloride
RAQ	Ressources Aquatique Québec
RAS	recirculating aquaculture system
RDC	Research and Development Corporation (NL)
(NB)RPC	(NB) Research and Productivity Council
RAS	recirculation aquaculture system
rRNA	Ribosomal RNA (ribonucleic acid)
RNAi	RNA interference
SABS	St. Andrews Biological Station
SÉPAQ	Société des établissements de plein air du Québec
SFU	Simon Fraser University
SINTEF	Stiftelsen for industriell og teknisk forskning (English: The Foundation for Scientific and Industrial Research) (Norway)
SNP	single nucleotide polymorphism
SODIM	Société de développement de l'industrie maricole inc.
SORDAC	Société de recherche et de développement en aquaculture continentale inc.
SSHRC	Social Sciences and Humanities Research Council of Canada
StFX	St. Francis Xavier University
UBC	University of British Columbia
UBO	Université de Bretagne Occidentale
UDEM	University of Montréal
UMCM	University of Moncton Moncton Campus
UMCS	University of Moncton Shippagan Campus
UNB	University of New Brunswick
UNBSJ	University of New Brunswick Saint John
U of T	University of Toronto
UPEI	University of Prince Edward Island
UQAR	University of Québec at Rimouski
UVic	University of Victoria
VHS	viral hemorrhagic septicemia
VIU	Vancouver Island University



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